A MONITORING PROGRAM FOR THE AMUR TIGER

NINTH-YEAR REPORT: 2005-2006

In accordance with the Russian National Strategy for Tiger Conservation

A cooperative project conducted by representatives of:

Wildlife Conservation Society
All Russia Research Institute of Wildlife Management, Hunting, and Farming
Institute of Geography, Far Eastern Branch of the Russian Academy of Sciences
Institute of Biology and Soils, Far Eastern Branch of the Russian Academy of Sciences
Sikhote-Alin State Biosphere Zapovednik
Lazovski State Zapovednik
Ussuriski Zapovednik
Botchinski Zapovednik
Bolshe-Khekhtsirski Zapovednik
Institute for Sustainable Use of Renewable Resources
World Wide Fund for Nature

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The Save-the-Tiger Fund
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PROJECT COORDINATORS:

Overall Coordinator:
Miquelle, Dale G., Wildlife Conservation Society, Russian Far East Program

Khabarovski Krai Coordinator
Dunishenko, Yuri. M. A, All Russia Research Institute of Wildlife Management, Hunting, and Farming

Primorski Krai Coordinators:
Aramilev, Vladimir V., Institute for Sustainable Use of Renewable Resources
Fomenko, Pavel. V. WWF, Russian Far East
Litvinov, Mikhail N., Ussuriski Zapovednik
Nikolaev, Igor G., Institute of Biology and Soils, Far Eastern Branch Russian Academy of Sciences
Pikunov, Dimitri G., Institute of Geography, Far Eastern Branch of the Russian Academy of Sciences
Salkina, Galina. P., Lazovski State Zapovednik
Seryodkin, Ivan V., Institute of Geography, Far Eastern Branch of the Russian Academy of Sciences
Smirnov, Evgeny N., Sikhote-Alin Biosphere State Zapovednik
Zaumyslova, Olga Yu. Sikhote-Alin Biosphere State Zapovednik

Data entry, Translations, Report Editing, and Project Management
Katerina Nikolaeva

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NINTH-YEAR REPORT: 2005-2006 WINTER

Executive Summary

Standardized survey techniques, agreed upon all collaborating biologists and scientific institutions, have been used since the 1997-1998 winter season to monitor the status of Amur tigers in the Russian Far East. These methods, and their accuracy in detecting change in numbers of tigers, have been detailed in a Russian publication "A theoretical basis for surveying tigers and their prey base in the Russian Far East.

The Amur Tiger Monitoring Program includes 16 monitoring units, totaling 23,555 km^2 (approximately 15-18% of suitable tiger habitat) which are surveyed to assess changes in tiger numbers using relative and absolute indicators of tiger abundance, cub production, and relative ungulate densities. A total of 246 survey routes are sampled twice each winter, representing 6114 km traversed in total.

All three indicators of tiger abundance (% routes tiger tracks detected, tiger track density, and expert assessment of tiger numbers) suggest that when averaged across all 16 sites, tiger abundance appears to be relatively stable. However, there are specific monitoring units where changes are clearly occurring. Sikhote-Alin Zapovednik and the adjacent Terney Hunting lease are areas of greatest concern, where all three indicators provide strong evidence that tiger numbers are decreasing. Two of three indicators also suggest that tigers numbers are decreasing in Ussuriski and Bolshekhekhtsirski Zapovedniks. It should be of concern that zapovedniks, which should represent core protected populations of tigers, are experiencing these declines, which may be a combination of effects, with poaching, and decreases in prey numbers (see below) probably contributing in all situations.

While some areas are experiencing declines, in other areas tiger populations appear to be increasing, in particular in Sineya (Chuguevski Raion) and possibly Mataiski Zakaznik and Tigrini Dom, both in Khabarovsk.

Cub production across monitoring sites appears to be spreading somewhat, as the percentage of monitoring units without cubs has dropped from a high of nearly 60% in 2003. Litter size also appears to have dropped since a high in 2003. Over the nine year monitoring period 5 of the 16 sites have produced 57% of the litters, and it is concerning that some of these sites (Ussuriski and Sikhote-Alin Zapovedniks) are experiencing declines in tiger numbers.

Red deer numbers are decreasing in nearly all monitoring sites in southern Primorye, apparently in relation to the increase in sika deer populations there. However, most of the monitoring units in the central and northern portions of tiger range have stable or increasing populations of red deer. Sika deer range appears to be expanding north, but in most sites where they occur sika deer numbers have been relatively stable, except in Borisovkoe Plateau, where they are experiencing a significant decline, which is of concern as this is core habitat for the isolated population of tigers in Southwest Primorye. Wild boar numbers nearly uniformly declined across most sites from 1998 through 2002, and now appear to be slowly recovering. As with red deer, roe deer numbers appear to be declining in most of the southern monitoring sites, also apparently in relation to high sika deer numbers, but are increasing or stable across most of the central and northern monitoring sites. Musk deer, which have been monitoring only since 2002, are rare in most sites, but where they occur, there appear to be serious declines in their numbers, probably associated with intensive harvest for musk glands.

Overall, the long-term monitoring program has demonstrated that there are shifting abundances of prey species, apparently due to their interactions. What this means for tigers is not completely clear, but presumably any increase in prey biomass, as appears to be occurring in southern Primorye, should be beneficial for tigers. Despite many reports of tiger poaching, tiger numbers appear to be generally holding their own across the region.

I. INTRODUCTION

At the international level, the Amur tiger (*Panthera tigris altaica*) is considered in danger of extinction. With only a few individuals remaining in China and an unknown number in North Korea, preservation of this animal has become primarily the responsibility of the Russian government and the Russian people. Accordingly, Russia has taken many steps to conserve this animal, starting with a ban of hunting in 1947. The Russian Federal government has since listed the animal as endangered (Russian Red Data Book), and has recently developed a National Strategy for Conservation of the Amur Tiger in Russia, as well as a Federal Program to implement the national strategy.

The recovery of the tiger after near extinction in the first half of this century (following the 1947 ban) has been fairly well documented through a series of surveys (Kaplanov 1947, Abramov 1962, Kudzin 1966, Yudakov and Nikolaev 1970, Kucherenko, 1977, Pikunov et al. 1983, Kazarinov 1979, and Pikunov 1990). Most recently, a range-wide survey provided a great deal of information on the distribution and status of tigers in the past decade (Matyushkin et al. 1996). Nonetheless, there remains a long standing need for a reliable and efficient means for monitoring changes in the tiger population.

The tiger is a rare, sparsely distributed, and secretive animal that is distributed across at least 180,000 km^2 of Primorski and Khabarovski Krais in southern Russian Far East. This combination of attributes make it a particularly difficult animal to count reliably, and the financial burden and logistical problems associated with range-wide surveys make it practically impossible to conduct full-range surveys with sufficient frequency to track changes in tiger abundance.

Nonetheless, there exists a need to monitor the tiger population on a regular (preferably yearly) basis. Such a monitoring program should serve a number of functions, including:

1. A monitoring program should act as an “early warning system” that can indicate dramatic changes in tiger abundance. Range-wide surveys, usually conducted between long intervals with no information, may come too late to allow a rapid response to a decline in numbers. Yearly surveys should serve to provide notice so that immediate conservation actions can be initiated.

2. Ultimately, tiger numbers, or at least trends in the tiger population, should be used as a basis to determine the effectiveness of conservation/management programs. In Russia, there have been tremendous efforts and significant support from regional, Krai-wide, federal, and international levels for implementation of tiger conservation efforts that range from anti-poaching programs to conservation education. All these efforts are aimed at protecting the existing Amur tiger population in Russia, yet without an accurate monitoring program that can determine trends in tiger numbers with statistical accuracy, the ultimate effectiveness of these conservation programs will remain unknown.

3. Among other indicators, a monitoring program should provide information on reproductive rate of the population, which may act most effectively as a predictor, or early indication of imminent changes even before there are dramatic changes in actual tiger numbers.

4. Changes in ungulate populations, as primary prey for tigers, may also provide important clues to potential impacts on tiger numbers.

5. Finally, changes in habitat conditions can also provide an indicator as to the present and future status of Amur tigers in the wild. Understanding the relationship of human impacts on habitat and tiger numbers is a difficult undertaking, but one way to gain better insight is to monitor specific sites over time to compare changes in human impacts with changes in tiger numbers.

In an attempt to address these needs, nearly all coordinators of the 1996 tiger survey have worked together to develop a reliable and effective monitoring program for Amur tigers. The task is a huge one, given the area involved and the logistics of working in a northern environment. The derived methodology has been tested over 5 years (1997-1998 winter through 2001-2002 winter season) and the results, as provided in the yearly reports, provides an indicator of the value of this program. .

II. GOALS AND OBJECTIVES

The ultimate goal of this program is the yearly implementation of a standardized system for collecting data that can be used to monitor changes in tiger abundance, and factors potentially affecting tiger abundance, across their present range in the Russian Far East. The intent is to provide a mechanism that will assess changes in the density of tigers, as well as other potential indicators of population status, within their current range over long periods of time. This methodology should provide a means of assessing the effectiveness of current management programs, provide a means of assessing new programs, and provide an "early warning system" in the event of rapid decreases in tiger numbers.

Objectives

Specifically, the objectives of this monitoring program are to:

1. Determine presence/absence of tigers on survey routes within count units as one indicator of trends in tiger numbers over time, and differences in tiger abundance among survey units in the Russian Far East.
2. Develop a standardized, statistically rigorous estimate of track density within count units as a second indicator of trends in tiger numbers over time, and differences in tiger abundance among survey units in the Russian Far East.
3. Develop an expert assessment of actual tiger numbers within count units as a third indicator of population trends over time.
4. Record presence of female tigers with young on count units across the range of tigers to monitor reproduction rates over time and identify areas of high/low productivity, and changes in reproduction over time.
5. Monitor trends over time in the prey base (large ungulates) of tigers within count units.
6. Record and monitor instances of tiger mortality within and in close proximity to count units.
7. Monitor changes in habitat quality.

III. METHODOLOGY

The methodology has been provided in all past reports, and is therefore not repeated here. Details of methodology can be requested from the WCS Russia Program.

Additionally, it is worth noting that in 2007 we have finally published a monograph "Theoretical basis for surveys of tigers and their prey in the Russian Far East" which provides much of the background, history, and development of survey approaches in the Russian Far East. Unfortunately, this monograph is presently only available in Russia, but is obtainable by contacting the WCS Russia Office (dalemiq@vlad.ru, nika1204@mail.ru, or call to the Vladivostok office at: 7-4232-41-00-33).

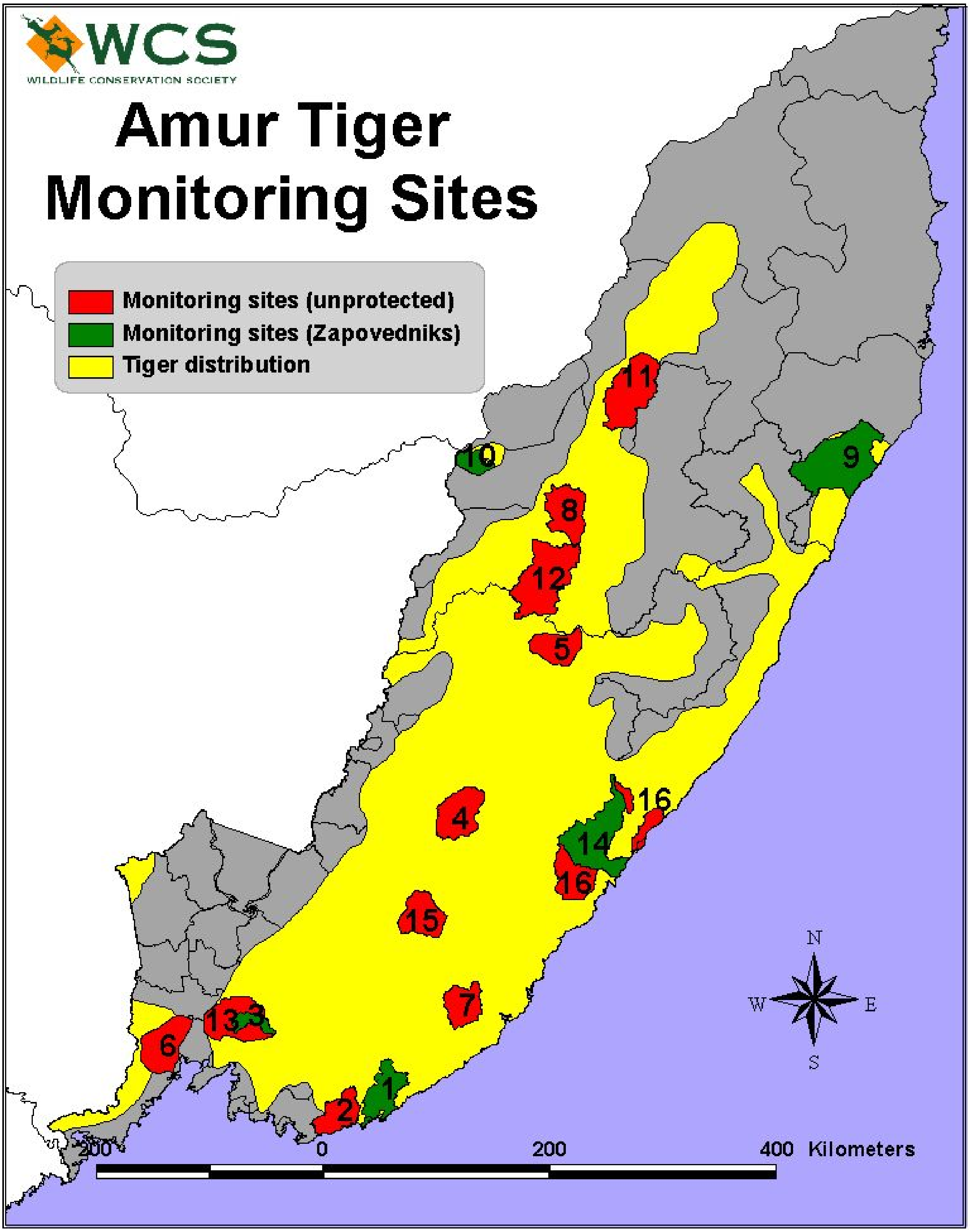

Figure 1. Location of the 16 sites used for monitoring Amur tigers in the Russian Far East. Numbers referenced in Table 1 and most other tables throughout text.

IV. RESULTS OF THE 2005-2006 WINTER MONITORING PROGRAM

Summary Data on Count Units and Routes

As in previous years, in the 2005-2006 winter the total area included in monitoring units was 23,555 km^2, or approximately 15-18% of the total area considered suitable tiger habitat, assuming either 156,571 (Matyushkin et al. Table 4) or 127,693 km^2 (Miquelle et al. 1999, Table 19.3) of suitable habitat.

A total of 246 survey routes were sampled (in nearly all units they were sampled twice), representing 3057 km of routes (with double sampling, a total of 6114 km traversed) (Table 3).

Table 1. Characteristics of units surveyed for Amur tiger monitoring program, 2005-2006.

	Monitoring Unit	Coordinator	Size of unit (km^2)	# survey routes	Total length of survey routes (km)	Average length of survey routes (km)	Survey route density (km/10 km2)
1	Lasovski Zapovednik	Salkina, G. P.	1192.1	12	121.4	10.1	1.02
2	Laso Raion	Salkina, G. P.	987.5	11	138.9	12.6	1.41
3	Ussuriski. Zapovednik	Litvinov, M. N.	408.7	11	104.4	9.5	2.55
4	Iman	Nikolaev. I. G.	1394.3	12	176.9	14.7	1.27
5	Bikin	Pikunov, D. G.	1027.1	15	188.4	12.6	1.83
6	Borisovkoe Plateau	Pikunov, D. G.	1472.9	14	216.8	15.5	1.47
7	Sandago	Aramilev, V. V.	975.8	16	218.5	13.7	2.24
8	Khor	Dunishenko, Yu. M.	1343.8	19	190.3	10	1.42
9	Botchinski Zapovednik	Dunishenko, Yu. M.	3051	14	164.7	11.8	0.54
10	BolsheKhekhtsir Zapovednik	Dunishenko, Yu. M.	475.6	7	82.9	11.8	1.74
11	Tigrini Dom	Dunishenko, Yu. M.	2069.6	14	181.8	12	0.88
12	Matai	Dunishenko, Yu. M.	2487.6	24	372	15.5	1.50
13	Ussuriski Raion	Litvinov, M. N.	1414.3	12	178.2	14.9	1.26
14	Sikhote Alin Zapovednik	Smirnov, E. N./ Zaumyslova, O. Yu.	2372.9	26	277.7	10.7	1.17
15	Sineya	Fomenko, P. V.	1165.4	15	207.2	13.8	1.78
16	Terney Hunting Society	Smirnov, E. N.	1716.5	24	247.2	10.3	1.44
	Totals		23555.1	246	3057.3	12.42805	1.30

Measures Of Tiger Abundance

Presence/Absence on Survey Routes

Reporting on zero counts on survey routes serves two purposes.

1) as noted in the Introduction, from a methodological perspective large numbers of zero counts are not desirable because they reduce our capacity to detect changes in tiger numbers, i.e., if a survey route never has an occurrence of tiger tracks reported, it does not provide information on changes in tiger numbers. Therefore, understanding the distribution of zero counts is an important component of understanding the effectiveness of the sampling design.

2) Presence/absence is used as one of three indicators used to assess abundance (in this case, relative abundance) of tigers in each monitoring unit by ranking monitoring sites based on the percentage of routes without tiger tracks.

We report the proportion of survey routes with tiger tracks recorded on either the early or late winter surveys. In the 2005-2006 winter on 59% of 246 routes on monitoring sites tiger tracks were reported (Table 2), very close to the 9-year average (57.7%). As an average across all sites, this value has fluctuated only slightly over the nine years of monitoring (Figure 2), suggesting that occupancy (presence of tigers) has remained fairly stable over that period.

Despite the apparent overall stability, there was great variation among sites in percentage of routes with tiger tracks in 2006, which varied from 100% for 4 sites (including the three which have maintained the highest occupancy rates over the monitoring period -Lazaovski Zapovednik, Lazovski Raion, and Ussuriski Zapovednik) to no tracks observed in BolsheKhekhtsirski Zapovednik (Table 2).

We looked for trends across time by conducting linear regression analyses on all sites combined, and each site separately. Where visual inspection of data suggested that there may have been important trends over portions of the 9-year monitoring period, we separately assessed those periods. Here we report on trend analyses that demonstrated $P < 0.2$ for the regression analysis. Although this is a liberal significance value, it allows us to be look for indicators of population change, and thus use this tool as an “early warning indicator” recognizing that false alarms (Type 1 statistical errors) are more likely. However, it is better to be concerned about a population even if it is in reality not decreasing, than to ignore potential early warning indicators.

Nine of sixteen monitoring sites showed trends, using the above criteria, with 4 showing evidence of increases, and five showing signs of decreases.

Occupancy rates were declining in Ussuriski Zapovednik from 1998-2005, but in 2006 there was a dramatic increase (Fig. 3a), suggesting that a greater area of the reserve was being used by tigers in the 2006 winter than in previous winters.

Track presence appears to be declining in the Bikin monitoring site (Fig. 3b). This relationship is relatively strong ($r^2 = 0.71$, $P = 0.008$) when the first year of monitoring is deleted from the trend analysis.

Table 2. Percentage of routes with tiger tracks (occupancy) based on two surveys/winter, 1998-2006 on survey units in the Amur Tiger Monitoring Program.

	YEAR									
Survey unit	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
Lazovski Zapovednik	91.7%	71.4%	100.0%	100.0%	100.0%	90.9%	91.7%	90.0%	100.0%	92.9%
Lazovski Raion	100.0%	57.1%	60.0%	45.5%	87.5%	88.9%	71.4%	45.5%	100.0%	72.9%
Ussuriski Zapovednik	87.5%	100.0%	88.9%	88.9%	77.8%	77.8%	66.7%	72.7%	100.0%	84.5%
Borisovskoe Plateau	45.5%	53.8%	41.7%	40.0%	41.7%	61.5%	36.4%	50.0%	100.0%	52.3%
Sandagoy	42.9%	54.5%	30.8%	46.2%	18.8%	72.7%	28.6%	37.5%	77.8%	45.5%
Iman	90.0%	63.6%	66.7%	90.0%	72.7%	54.5%	77.8%	28.6%	75.0%	68.8%
Bikin	35.7%	85.7%	84.6%	91.7%	76.9%	80.0%	66.7%	61.5%	69.2%	72.5%
Sikhote Alin Zap	88.0%	78.3%	77.8%	68.4%	57.1%	76.2%	38.1%	45.5%	68.2%	66.4%
Botchinski Zap	50.0%	45.5%	85.7%	100.0%	37.5%	50.0%	20.0%	81.8%	60.0%	58.9%
Mataiski Zakaznik	35.3%	72.2%	29.4%	47.4%	57.1%	56.3%	72.2%	90.5%	52.9%	57.0%
Sineya	33.3%	30.0%	27.3%	27.3%	21.4%	50.0%	45.5%	40.0%	50.0%	36.1%
Ussuriski Raion	60.0%	20.0%	100.0%	20.0%	50.0%	28.6%	62.5%	28.6%	40.0%	45.5%
Tigrini Dom	41.7%	50.0%	60.0%	76.9%	61.5%	66.7%	85.7%	88.9%	30.8%	62.5%
Terney Hunting Lease	61.9%	57.9%	42.1%	50.0%	20.0%	31.6%	4.5%	22.7%	15.8%	34.1%
Khor	25.0%	27.8%	87.5%	42.9%	25.0%	46.7%	41.2%	44.4%	12.5%	39.2%
Bolshekhekhtsirki Zap	75.0%	42.9%	80.0%	14.3%	16.7%	0.0%	33.3%	50.0%	0.0%	34.7%
Total	60.2%	56.9%	66.4%	59.3%	51.4%	58.3%	52.6%	54.9%	59.5%	57.7%

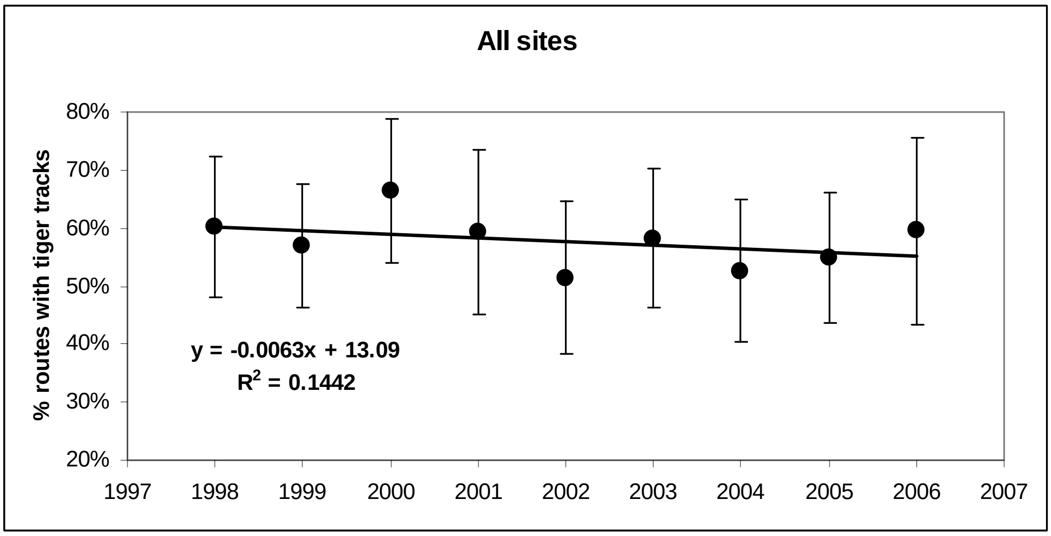

Figure 2. Overall trends in presence of tiger tracks on routes, averaged for all 16 sites of the Amur Tiger Monitoring Program, from the 1997-1998 winter through 2005-2006 winter seasons.

Perhaps the strongest evidence for a decline in occupancy comes from Terney Raion, where both Sikhote-Alin Zapovednik and the adjacent territory in Terney Hunting lease demonstrate strongly significant downward trends (Figs. 3c and 3d).

Bolshekhekhtsirski Zapovednik continued to show a decline in occupancy, with the second of the past three years with no tracks reported on survey routes (3e).

Borisovkoe Plateau had a basically stable presence-absence pattern until 2006 (Fig. 3f), when a sharp increase to 100% of routes had tiger sign, resulting in a significantly ($p > 0.2$) positive pattern. However, this dramatic increase may be an artifact of especially deep snows in 2006, which may have forced tigers onto roads (where most of the routes are). Results of 2007 will be interested to assess in this relation.

Tigrini Dom and Mataiski Zakaznik showed consistent increases in occupancy except for 2006 (Figs. 3g and 3h), when occupancy rates dropped at both sites. Results in 2007 may provide insight as to whether 2006 was an anomaly, or represents a new pattern of decline. Both sites are in Khabaraovski Krai, and the simultaneous decline (along with BolsheKhekhtsirski) in 2006 may be reason for concern.

Sineya monitoring site is the only other place where there has been evidence of a relatively strong increase in occupancy rates ($r^2 = 0.447$, $P = 0.049$) (Fig. 3g).

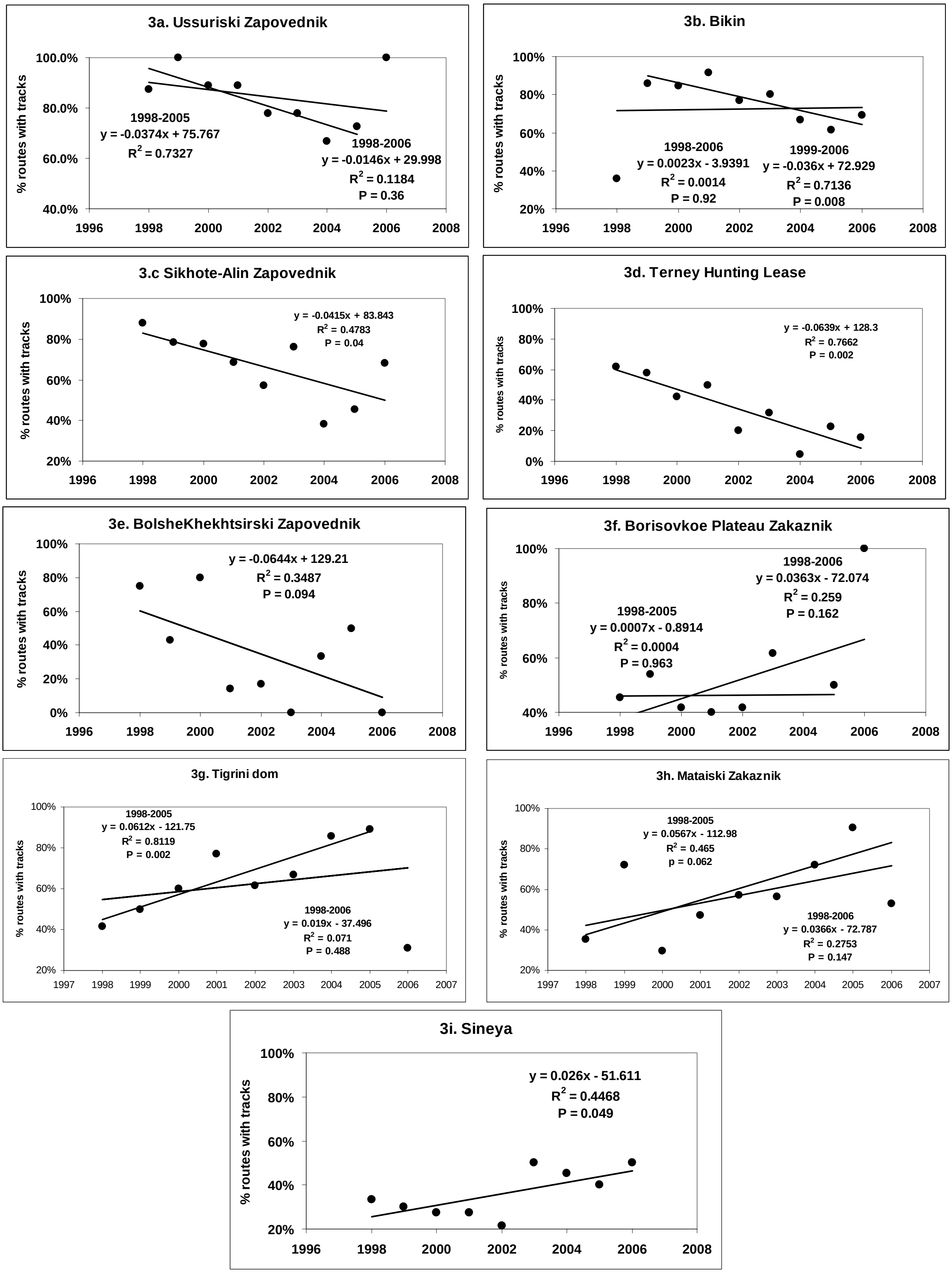

Figure 3a-i. Monitoring units which have shown a drop or increase (P < 0.2 for the regression) in percentage of survey routes with tiger tracks found across all 6 years of the Amur Tiger Monitoring Program, 1997-1998 through 2005-2006 winter seasons. Bolshekhetsirski is included for comparison to status in previous year.

Track Counts on Survey Routes

Mean track density, adjusted for the number of days since the last snowfall (see Methods), provides an indication of relative abundance of tigers on monitoring sites (Table 3). As in most years, track density estimates varied greatly between sites, with Ussuriski Zapovednik retaining the highest track density (4.2 ± 2.3 tracks/100 km/days since snow), and the Khor monitoring site, in Khabarovsk, reporting the lowest track density (0.26 ± 0.24). Overall, zapovedniks in southern Primorye tend to report the highest track densities (Ussurski, Lazovski Zapovedniks in particular) but the Bikin River monitoring site has also traditionally reported very high track densities (Table 3). And, as expected, the monitoring sites to the north, in Khabarovsk, tend to report the lowest track densities,

We looked for trends in the tiger population using track data by applying a regression analysis to all 16 monitoring sites averaged for each year, but because differences in sites may be masked by averaging, we also pay attention to trends in individual sites. When looking at the overall regression for 9 years combined over all 16 monitoring units, there is clearly no significant trend in track density ($r^2 = 0.18$, $P = 0.244$) (Figure 4). The overall mean track density was one of the lowest reported over the 9 nines (Table 3), and the lowest of the past three years. A visual inspection of Figure 4 suggests that tiger track densities may have been higher in the earlier years of the monitoring program, but a comparison of mean track densities for all units combined for two periods (1998-2001 and 2002-2006) shows no significant difference (Figure 5), even though the mean track density is lower in the second period.

We compare tiger track density for each monitoring unit (Figures 6a-i) with occupancy rates (Figures 3a-i) to assess whether track density trends corroborate results of the occupancy rate trend assessment for each survey unit. For Ussuriski Zapovednik, the significantly negative trend ($r^2 = 0.625$, $P = 0.019$) in tiger track density for the years 1999-2006 (Figure 6a) strongly

Table 3. Track density (tracks/100 km/days since snow) of tigers on 16 survey units for 9 years of the Amur Tiger Monitoring Program, 1998-2006

		YEAR									
Survey Unit	Krai	1998	1999	2000	2001	2002	2003	2004	2005	2006	Overall Mean
Ussuriski Zapovednik	Primorye	3.28	9.66	6.45	6.15	3.49	2.62	2.12	2.71	4.20	4.52
Lazovski Zapovednik	Primorye	3.62	2.19	3.09	3.57	2.52	3.50	4.15	2.35	3.56	3.17
Bikin	Primorye	3.61	7.71	0.95	3.70	2.31	2.63	6.34	0.61	2.45	3.37
Sineya	Primorye	0.24	0.33	0.55	0.58	0.38	0.58	0.86	0.57	1.76	0.65
Lazovski Raion	Primorye	1.44	0.67	0.99	1.02	1.62	0.93	1.34	0.44	1.32	1.09
Borisovskoe Plateau	Primorye	0.50	0.85	1.45	0.60	0.51	1.17	0.71	0.74	1.23	0.86
Ussuriski Raion	Primorye	1.01	0.61	1.93	1.44	1.70	0.56	0.72	0.46	0.96	1.04
Sikhote Alin Zap	Primorye	1.99	1.28	1.52	1.18	0.91	1.04	1.06	0.91	0.93	1.20
Botchinski Zapovednik	Khabarovsk	0.88	0.74	1.18	1.29	1.04	0.46	0.58	0.77	0.81	0.86
Sandagoy	Prim	0.47	0.66	0.34	0.41	0.23	0.83	0.40	0.39	0.67	0.49
Iman	Prim	0.96	2.81	1.00	0.76	0.81	0.65	0.52	0.64	0.63	0.98
Mataiski Zakaznik	Khabarovsk	0.63	1.18	0.73	2.42	0.38	0.39	0.59	2.46	0.53	1.03
Tigrini Dom	Khabarovsk	0.67	1.47	1.13	1.51	1.66	1.27	2.21	1.51	0.31	1.30
Terney Hunting Lease	Primorye	0.83	0.64	0.73	0.90	0.39	0.61	0.15	0.40	0.27	0.55
Bolshekhekhtsirki Zapovednik	Khabarovsk	1.99	1.47	0.84	0.71	0.71	0.42	7.14	1.81	0.26	1.71
Khor	Khabarovsk	0.44	0.80	1.67	1.50	1.35	0.45	1.05	4.39	0.26	1.32
Overall Mean		1.41	2.07	1.53	1.73	1.25	1.13	1.87	1.32	1.26	1.51

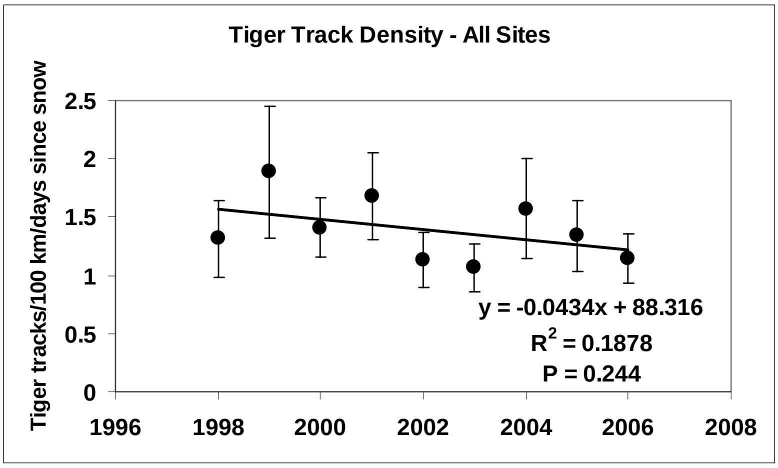

Figure 4. Density of tiger tracks (tracks/100 km/days since last snow) as an indicator of relative tiger abundance averaged across 16 sites included in the Amur Tiger Monitoring Program, winter 1997-1998 through 2005-2006.

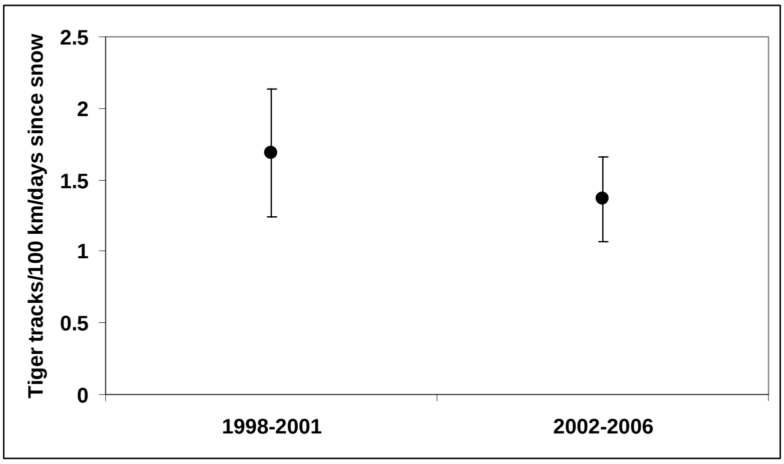

Figure 5. Comparison of tiger track densities in two periods, 1998-2001, and 2002-2006 in 16 monitoring units of the Amur Tiger Monitoring Program.

supports evidence from the occupancy data (Figure 3a) that tiger numbers are decreasing there. In the Bikin there is no evidence from the track data that tiger numbers are decreasing (Figure 6b), in contradiction to the occupancy data (Figure 3b) that does indicate a decrease in the percentage of routes with tiger tracks reported. For both Sikhote-Alin Zapovednik (Figures 3c and 6c) and the neighboring territory in Terney Hunting Lease (Figures 3d and 6d), the occupancy data and tiger track data collectively provide strong evidence of a negative trend in tiger numbers in southern Terney Raion. The tiger track density data for Bolshekhekhtsirski Zapovednik (figure 6e) does not support the occupancy data that suggests a decrease in tigers (Figure 3e), but the trend line was not strong for the occupancy data to begin with. Similarly, the track data for the Borisovskoe Plateau (Figure 6f) does not support the analysis of occupancy (Figure 3f) that indicated a potential increase – again with a relatively weak trend coefficient for occupancy to begin with. The track density data from Tigrini Dom (Figure 6g) does coincide with occupancy data (Figure 3g), collectively providing strong evidence that tigers were increasing there until 2004 or 2005, and have subsequently suffered a decrease in numbers. The tiger track density data for Matai Zakaznik (Figure 6h) does not support evidence of an increase in relative abundance of tigers that might be derived from the occupancy data (Figure 3h). Finally data from both the occupancy trend analysis (Figure 3i) and the tiger track data (Figure 6i) from Sineya support the hypothesis that relative abundance of tigers there is increasing.

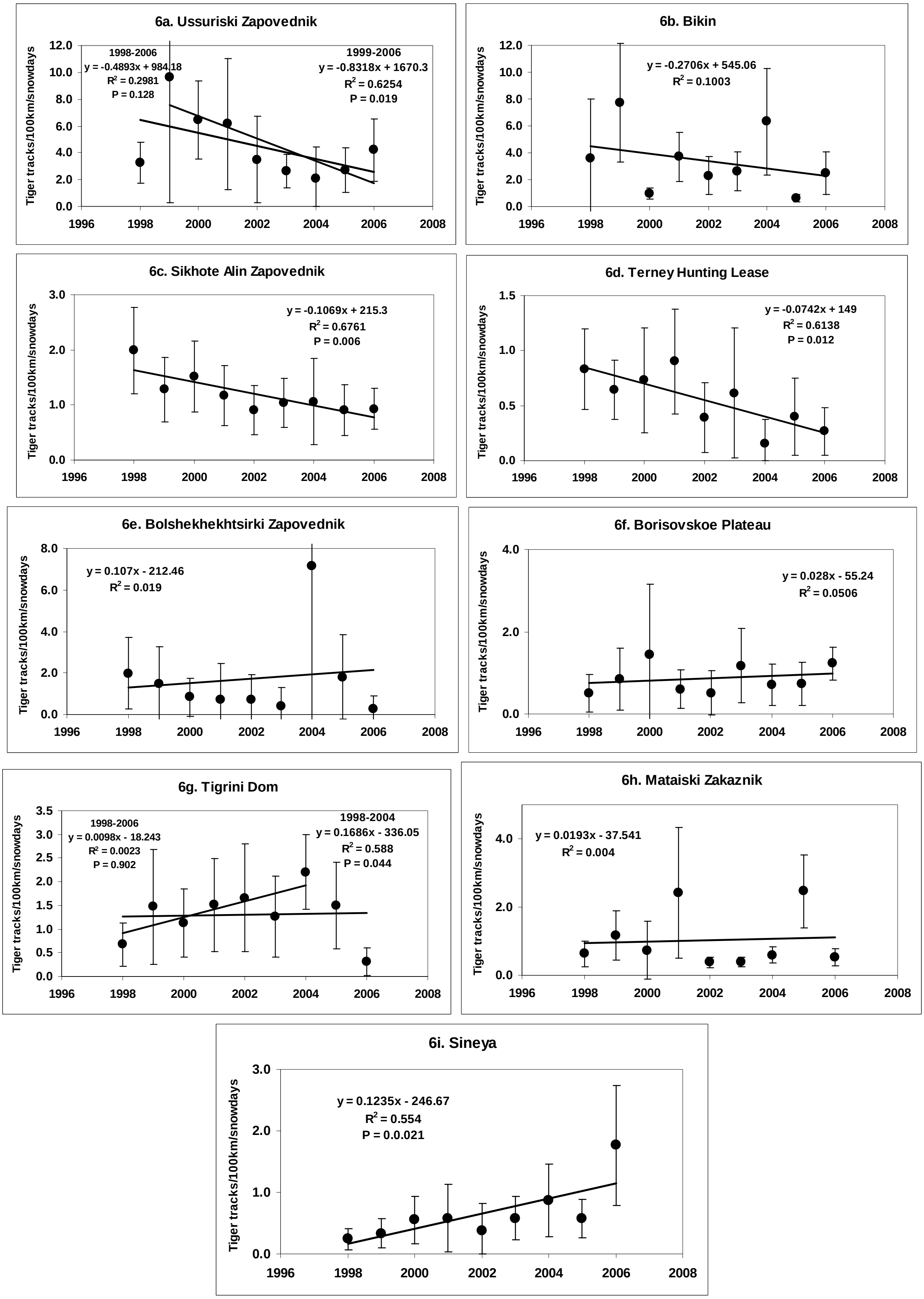

Figure 6a-h. Track density (tracks/100 km/days since last snow) and trends for 9 of the 16 sites of the Amur Tiger Monitoring Program, to be compared to trends in occupancy in Figure 3a-i..

Expert Assessment of Tiger Numbers on Monitoring Sites

We maintained consistency in having the same coordinators make expert assessments on each of the 16 monitoring units across the range of Amur tigers in the Russian Far East for the first seven years of the program. In 2004 V.K. Abramov passed away, and two monitoring units (Ussuriski Zapovednik and Ussuriski raion) have been coordinated by his assistant, M. Litvinov. In Sikhote-Alin Zapovednik E.N. Smirnov retired in 2006, and responsibilities for monitoring tigers was gradually shifted over to O. Zaumyslava in the Zapovednik. Although there is known to be variation among coordinators in how they interpret track data to estimate tiger numbers, there was a strong relationship between how all coordinators of the 2005 tiger survey (who are mostly the same people who do yearly monitoring) interpreted tiger tracks, and interpretation done by a standardized algorithm (Miquelle et al. 2007). Because of consistency in personnel, we believe that the year to year estimates within any given unit are likely to reflect real changes in tiger numbers, assuming coordinators interpret track data consistently. While the variation among coordinators (and therefore among sites) is more difficult to account for, we believe providing estimates of tiger abundance across all sites provides a mechanism for comparing density across the range of tigers.

A total of 110 adult tigers and 28 cubs reported on all 16 sites combined represented a slightly above-average year for tiger numbers (9-year average is 102 adults and 25 cubs) for the 9 years the monitoring program has been ongoing (Table 4). Overall tiger densities appear to be slightly higher over the past two years than in the past five years (Figure 7, Table 5) but not significantly so.

Tiger density has averaged about 0.5 adults&subadults/100 km^2 across all sites for all nine years, and although that average has fluctuated some (Figure 7), the variation has been relatively minor; overall, tiger density appears to be fairly stable across all sites combine. However, tiger density varied ten-fold across monitoring units, from 1.47 animal/100 km^2 in Ussuriski Zapovednik (which has been consistently the monitoring site with highest densities across nearly all years) (Table 5), to 0.133/100 km^2 in Botchinski Zapovednik (Table 5).

The three southern and central zapovedniks (Ussuriski, Lazovski, and Sikhote-Alin) have retained the highest 9-year average densities (Table 5), indicating the importance of protected areas in tiger conservation strategies. As expected, 5 of the 6 monitoring sites with the lowest tiger densities are in Khabarovski Krai, reflecting the harsher conditions in this most northern distribution of tigers.

As with other indicators of abundance, although expert assessments of tiger densities appeared to be stable when averaged across all sites, individual sites continue to show a range of trends: in 2006 three sites had significantly negative trends, and three had significantly position growth trends. Altough Ussuriski Zapovednik showed significantly downward trends using occupancy and tiger track indices (Figures 3a, 6a), the density estimate based on expert assessments appears relatively stable (8a). In the Bikin, although the occupancy (Figure 3b) and track density indicators (Figure 6b) had significant and non-significant downward trends, the expert assessment suggests that tiger numbers are stable (Fig. 6b). Trend analyses of tiger densities for Sikhote-Alin Zapovednik and Terney Hunting Lease support the conclusions based on occupancy and track density, that tigers are decreasing significantly over the 9-years of observations (Figures 8c-d). At Sineya monitoring site there did not appear to be a strong indication of increase in tiger densities based on expert assessments, although the upward tendency of the data is in line with strong upward trends based on occupancy and track densities. The trend displayed for Borisovkoe Plateau (Figure 8f), is not strong (r^2 – 0.278, P = 0.144) is negative, as opposed to a weak upward trend in the occupancy data set (Figure 3f). Evidence of increases in tiger numbers in both Tigrini Dom (figure 8g) and Mataiski Zakazanik (Figure 8h), although weak for Tigrini Dom, are nonetheless congruent with positive trends in the occupancy (Figures 3g-h) and track data (Figures 6g-h). Although no trends were discerned in either the occupancy or track data sets, there is nonetheless a significant upward trend in the expert assessments of tiger density (Figure 8j).

Table 4. Number of independent tigers (adults, subadults, and unknown), based on expert assessments of tiger tracks on 16 sites in the Russian Far East Amur Tiger Monitoring Program, during the first nine years of monitoring, 1998 through 2006.

Monitoring unit	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
Lazovski Zapovednik	6	9	10	11	12	9	10	13	14	94
Lazovski Raion	8	4	5	4	6	5	4	8	6	50
Ussurisk Zapovednik	6	10	4	5	4	6	7	10	6	58
Iman	8	6	5	6	6	4	5	8	5	53
Bikin	3	10	7	6	7	8	5	5	12	63
Borisovskoe Plateau	4	5	4	3	3	5	3	3	3	33
Sandagoy	6	6	5	7	3	7	5	6	7	52
Khor	3	4	4	4	4	5	5	5	6	40
Botchinski Zapovednik	3	3	4	4	6	4	2	5	4	35
Bolshekhekhtsirki Zapovednik	2	1	2	1	1	1	2	2	1	13
Tigrini Dom	4	6	4	4	5	6	5	7	4	45
Mataiski Zakaznik	3	5	4	4	5	5	5	9	9	49
Ussuriski Raion	6	1	2	2	9	6	5	8	5	44
Sikhote Alin Zapovednik	21	21	23	17	17	16	12	19	16	162
Sineya	5	6	5	7	5	7	5	6	6	52
Terney Hunting Lease	10	11	13	11	5	7	3	8	6	74
Total	98	108	101	96	98	101	83	122	110	917

Table 5. Density of independent tigers (adults, subadults, and unknown), based on expert assessments of tiger track on on 16 sites in the Russian Far East Amur Tiger Monitoring Program, during the first seven years of monitoring, 1998 through 2006.

Monitoring unit	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
Ussurisk Zapovednik	1.468	2.447	0.979	1.223	0.979	1.468	1.713	2.447	1.468	1.577
Lazovski Zapovednik	0.503	0.755	0.839	0.923	1.007	0.755	0.839	1.091	1.174	0.876
Sikhote Alin Zapovedn	0.885	0.885	0.969	0.716	0.716	0.674	0.506	0.801	0.674	0.759
Bikin	0.292	0.974	0.682	0.584	0.682	0.779	0.487	0.487	1.168	0.682
Sandagoy	0.615	0.615	0.512	0.717	0.307	0.717	0.512	0.615	0.717	0.592
Lazovski Raion	0.810	0.405	0.506	0.405	0.608	0.506	0.405	0.810	0.608	0.563
Sineya	0.429	0.515	0.429	0.601	0.429	0.601	0.429	0.515	0.515	0.496
Terney Hunting Lease	0.583	0.641	0.757	0.641	0.291	0.408	0.175	0.466	0.350	0.479
Iman	0.574	0.430	0.359	0.430	0.430	0.287	0.359	0.574	0.359	0.422
Ussuriski Raion	0.424	0.071	0.141	0.141	0.636	0.424	0.354	0.566	0.354	0.346
Khor	0.223	0.298	0.298	0.298	0.298	0.372	0.372	0.372	0.446	0.331
Bolshekhekhtsirki Zap	0.421	0.210	0.421	0.210	0.210	0.210	0.421	0.421	0.210	0.304
Borisovskoe Plateau	0.272	0.339	0.272	0.204	0.204	0.339	0.204	0.204	0.204	0.249
Tigrini Dom	0.193	0.290	0.193	0.193	0.242	0.290	0.242	0.338	0.193	0.242
Mataiski Zakaznik	0.121	0.201	0.161	0.161	0.201	0.201	0.201	0.362	0.362	0.219
Botchinski Zapovednik	0.098	0.098	0.131	0.131	0.197	0.131	0.066	0.164	0.131	0.127
Total	0.494	0.573	0.478	0.474	0.465	0.510	0.455	0.639	0.558	0.516

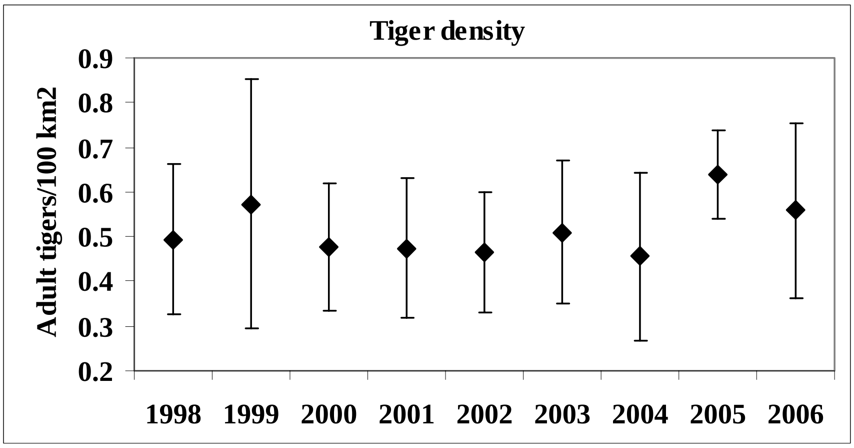

Figure 7. Density of independent tigers (adults and subadults) counted on monitoring units, based on expert assessments for 16 sites in the Amur Tiger Monitoring Program, 1997-1998 through 2005-2006 winter seasons.

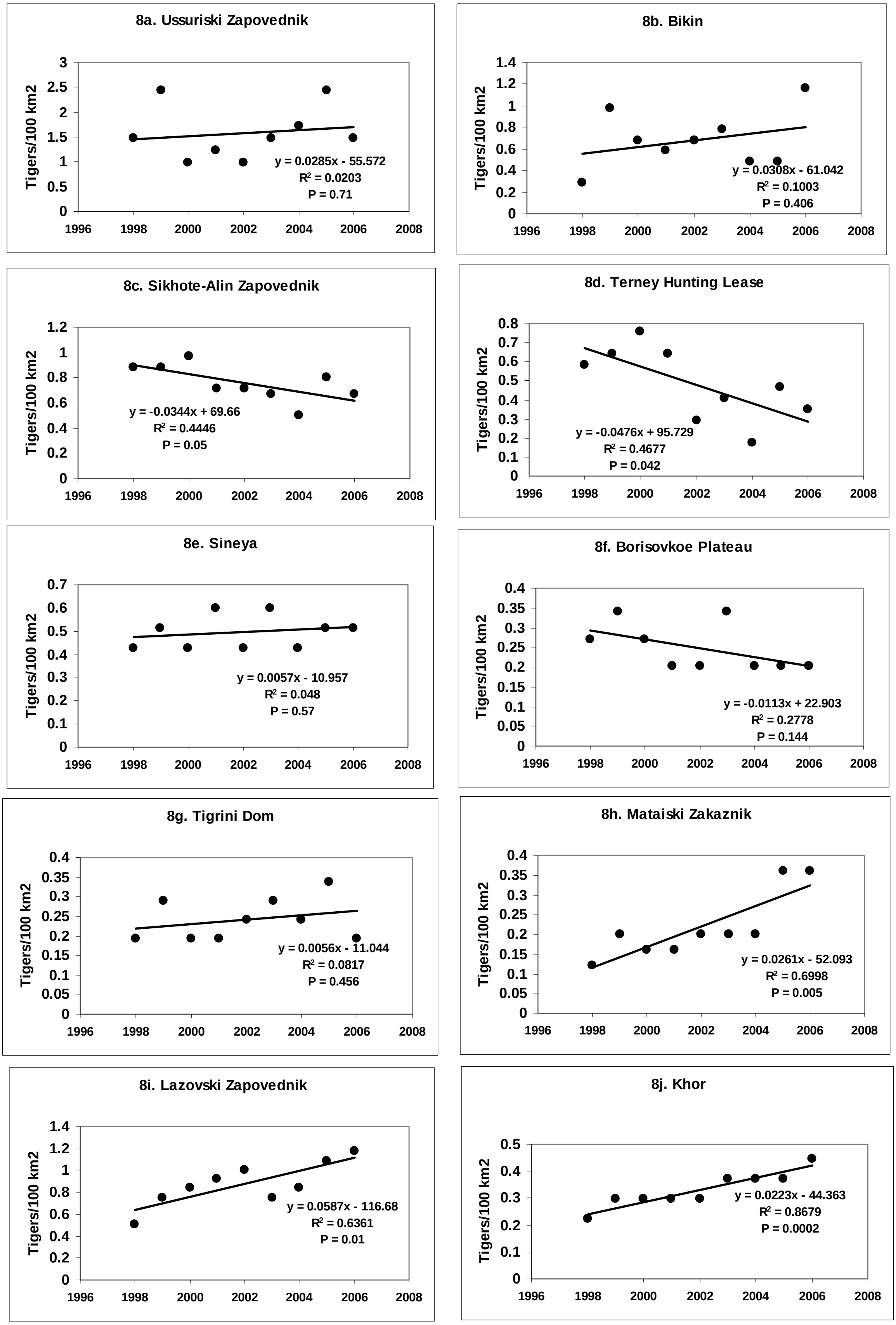

Figure 8a-j. Trend regression analyses for individual monitoring sites with P-values < 0.20 for changes in density of independent tigers across the six years of the monitoring program, winters 1998 through 2006.

Assessment of Trends in Numbers of Amur Tigers over the past Nine Years

We use three indicators to assess changes in the status of the Amur tiger population in the Russian Far East over the past nine years: occupancy, track density, and expert estimates of tiger density. Because any single measurement has its inherent biases and errors associated with it, we believe that by using a weighting system that compares these three estimators will give a more balanced assessment of the status of tigers at any given point of time and in any given monitoring unit. Our monitoring program is designed not to provide an assessment of the absolute numbers of tigers in either Primorski or Khabarovski Krai, but to provide an assessment of changes in numbers. We believe that such a monitoring system, if sufficiently accurate, should act as an "early warning signal" which will allow the appropriate governmental agencies to react with this information. Thus, based on an assessment of the trends identified above, we believe there are a number of important conclusions that can be drawn.

We summarize the results of the three analyses of tiger abundance in Table 6. We record each instance where a potential trend was identified (i.e. the p-value, which provides an estimate of the probability of a trend being real, is less than 0.2) for each of the monitoring sites for each of the three estimators of tiger abundance. If a significant positive trend was present, we grade each such episode as "+", and similarly, each significant negative trend as a "-". Summing for each monitoring site, we can derive values ranging from complete agreement that a population is increasing (+100) to complete agreement that a population is decreasing ("-100"). Because there are three indicators, gradations come in thirds (e.g., 33, 66).

For half of the monitoring sites, all three indicators were in agreement concerning the trend of tigers in that site, while in 7 sites there was some combination of neutral estimators (no indication of change) and either a decrease or decrease. In only one site were there conflicting results where one estimator suggested an increase in tiger numbers, while another suggested a decrease (Borisovkoe Plateau). In this particular case, there was large variance in estimates, and the level of significance in each case was marginal. Most likely, there is too much "noise" at this particular site to determine with any degree of confidence what is the true trend for this region.

The results provide strong evidence that southern Terney Raion, including Sikhote-Alin Zapovednik and Terney Hunting Lease, is an area of great concern. If only one or the other demonstrates such strong negative trends, the results might be of suspect, but the fact that two adajacent sites demonstrate strongly negative trends for all three indicators provides powerful evidence that tiger numbers are on the decline, and have been for some time now. Attention to this region should be a priority for conservation efforts in the immediate future to determine the case of decline (see section below on ungulates), and to take appropriate action to reverse this trend.

Two other monitoring sites should be areas of concern. Two indicators suggest that tiger numbers may be declining in Ussuriski Zapovednik. This is of special concern because tiger densities here have traditionally been the highest in Russia, and loss of tigers here will represent a blow to the entire population. In close proximity to both Ussurisk, Artyom, and Vladivostok, Ussuriski Zapovednik suffers human pressures on 3 of its 4 sides, and should act as an important barometer of human influences on the tiger population. Hence, declines in Ussuriski Zapovednik may be taken as a potential indicator of increasing human pressures.

Bolshekhekhetsirski Zapovednik represents an isolated island of habitat, and it is perhaps to be expected that tiger numbers and densities will vary dramatically here. A loss or addition of a single individual greatly changes the estimate of density, and because it is isolated, this population can be expected to be ephermal, changing in density often, and occasionally blinking out completely. However, as long as corridors are retained with the greater Sikhote-Alin system, recolonization will still be highly likely, as this is a high quality, though small patch of tiger habitat.

Table 6. Comparison of three estimators of tiger abundance on 16 monitoring sites of the Amur Tiger Monitoring Program. Sites are ranked from areas of greatest concern (where all three indicators suggest tigers are decreasing) to areas of least concern (where all three indicators suggest tiger numbers are increasing). Based on data from 9 winters (1998 through 2006). Ratings represent the percentage of agreement in estimators, and the direction in trend (decreasing/increasing) of the population.

		Tiger abundance						
#	Monitoring unit	% tiger presence on rtes	Tiger track density	Tiger density	Rating	Conflicting results	Scale of Concern	
14	Sikhote-Alin Zapovednik	-	-	-	-100			Great concern:
16	Terney Hunting lease	-	-	-	-100			areas where tigers
3	Ussuriski Zapovednik	-	-	0	-66			are decreasing
10	Bolshe Khekhtsirski Zapovednik	-	0	-	-66			
5	Bikin River	-	0	0	-33			
2	Lazovski Raion	0	0	0	0			
4	Vaksee (Iman)	0	0	0	0			
6	Borisovkoe Plateau	+	0	-	0	+		
7	Sandagoy (Olginski Raion)	0	0	0	0			
9	Botchinski Zapovednik	0	0	0	0			
13	Ussuriski Raion	0	0	0	0			
1	Lazovski Zapovednik	0	0	+	33			
8	Khor	0	0	+	33			
11	Tigrini Dom	+	+	0	66			Areas where tigers
12	Matai Zakaznik	+	0	+	66			are increasing:
15	Sineya (Chuguevski Raion)	+	+	+	100			No concern

Six of the sixteen monitoring sites appear to retain stable, if relatively low densities of tigers (Lazovski raion, Iman, Sandagoy, Botchinski Zapovednik, and Ussuriski Raion), and may be representative of the vast majority of tiger habitat in Russia, with tigers more or less stable, but at very low densities (e.g. 0.3 – 0.5 tigers/100 km^2). Tigers can probably continue to survive at such low levels as long as ungulate numbers do not continue to fall, and as long as there remain large tracts of intact forests, essential to retain adequate numbers if density is so low.

In Khabarovski Krai, two sites, Tigrini Dom and Mataiski Zakaznik, there is relatively strong evidence of tiger numbers increasing (Table 6). This conclusion is in concurrence with results of the 2005 winter survey, which indicates that tiger distribution is expanding to the north, suggesting that conditions in this northernmost region are improving for tigers. Only one site in Primorski Krai (Sineya in Chuguevski raion) showed strong evidence of increasing numbers of tigers, but the fact that this site is in the central portion of tiger habitat in Primorye, is a ray of hope.

The pattern that emerges from this assessment is that there is great variation in trends of tiger numbers across their range, making it difficult to extrapolate to the total population. Trends vary greatly, often even between sites that are relatively close to each other, suggesting that local conditions (amount of protection, prey condition) have greater influences than any regional factors. The results suggest that monitoring is desireable on an even greater scale in order to detect regional changes. Attempting to extrapolate to the entire population from these 16 sites can be done only at the risk of greatly underestimating the amount of variation that occurs in trends and tiger densities across the range of this subspecies.

Reproduction on Monitoring Sites

Expert assessments of tiger numbers and sex-age structure provide an opportunity to track changes in reproduction over time. We adjusted the number of litters in each monitoring unit to include tracks of cubs that were reported without adult females. These individuals may represent either young cubs temporarily without mothers, or cubs which have lost their mothers, but nonetheless they represent reproduction that has occurred on or partially on the monitoring units. Therefore, we have attempted to include such individuals in our estimates for this year.

Since the 1997-1998 winter, the number of litters reported on all sites combined has ranged from 11 to 26, with the 18 litters reported for the 2006 winter, slightly above the 9-year average of 17 (Table 7, Figure 9). The number of cubs reported for this year (26) was also slightly higher than the 9-year average of 24 (Table 8). The percentage of monitoring units without cubs has ranged from 18.7 to 56.7%, with this past winter (2005-2006), at 31%, close again to the 9-year average of 35%. In general, these values suggest that reproduction across the range was close to overall average for the 2006 winter monitoring period.

What had been an unusual situation in regards to tiger reproduction on monitoring sites appears to be stablizing. Total cub production on all 16 units appeared to have dropped through the first three years of monitoring, and then rise through 2002. Although the number of monitoring units with cubs was decreasing through 2003 (Figure 10), the total cub production remained relatively stable because mean litter size was increasing (Figure 11). This was a potentially dangerous scenario since mean litter size cannot increase indefinitely. Cub production has subsequently picked up in some of these “poorer” sites, and hence the percentage of monitoring sites without cubs have decreased (Figure 10). Oddly enough, the mean litter size has more or less tracked the percentage of sites with cubs (compare Figures 10 and 11), resulting in a fairly steady cub and litter production over the past 6 years (Figure 9). Total cub and litter production are close to the overall average, but this is being achieved by a more broad distribution of reproduction occurring across more sites. Why mean litter size might track the percentage of sites producing cubs is unclear. Similarly, it is unclear what might be responsible for the changes in mean litter size (Figure 11, Table 9), but there appears to have been a clear drop and then rebound in litter size over the period of observation.

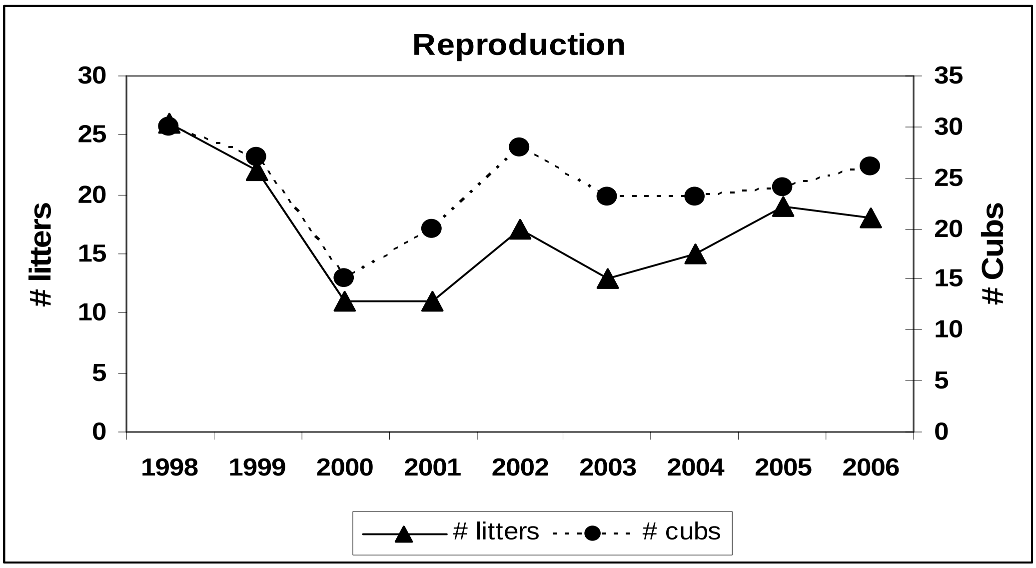

Figure 9. Total number of cubs and litters produced on all 16 units combined for the 9 winter seasons, 1998 through 2006, for the Amur Tiger Monitoring Program.

Table 7. Number of litters produced on each monitoring unit for 7 winters, 1998 through 2006, based on expert assessments of tiger tracks for the Amur Tiger Monitoring Program.

	Litter production									
Monitoring unit	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total litter production
1 Lazovski Zapovednik	1	1		2	2	3	1	2	5	17
2 Lazovski Raion	3	2		1	4	1	2			13
3 Ussurisk Zapovednik	3	4	1	1	2	1	2	2	3	19
4 Iman		2	1	1	1			1		6
5 Bikin	3		1		1	2		1	1	9
6 Borisovskoe Plateau	2	1	1	1		1		1		7
7 Sandagoy	3	1			1		1	1		7
8 Khor	1	1			1		1	2	1	7
9 Botchinski Zapovednik	1		2	1			1	1	1	7
10 Bolshekhekhtsirki Zapovednik		1								1
11 Tigrini Dom		1	1	1	2		1		1	7
12 Mataiski Zakaznik	3	2	1		1	2	2	1	1	13
13 Ussuriski Raion		1					1	1	1	4
14 Sikhote Alin Zapovednik	4	3	2	2		3	2	5	3	24
15 Sineya	1				1		1	1		4
16 Terney Hunting Lease	1	2	1	1	1				1	7
Totals	26	22	11	11	17	13	15	19	18	152

Table 8. Number of cubs produced on each monitoring unit for 7 winters, 1998 through 2006, based on expert assessments of tiger tracks for the Amur Tiger Monitoring Program.

	Cub production									
Monitoring unit	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total cub production
1 Lazovski Zapovednik	2	2		5	4	7	3	3	7	23
2 Lazovski Raion	3	3		3	7	1	3	0	0	20
3 Ussurisk Zapovednik	4	4	3	2	4	3	4	4	5	24
4 Iman		3	2	2	1			1	0	8
5 Bikin	3		1		2	2		1	0	8
6 Borisovskoe Plateau	2	1	1	1		2		1	0	7
7 Sandagoy	4	1			2		1	1	0	8
8 Khor	1	1			1		1	3	1	4
9 Botchinski Zapovednik	1		2	2			2	1	1	7
10 Bolshekhekhtsirki Zapovednik		1						0	0	1
11 Tigrini Dom		1	1	1	2		1	0	1	6
12 Mataiski Zakaznik	4	2	2		1	4	3	1	1	16
13 Ussuriski Raion		2					2	1	2	4
14 Sikhote Alin Zapovednik	4	4	2	3		4	2	6	6	19
15 Sineya	1				3		1	1	0	5
16 Terney Hunting Lease	1	2	1	1	1			0	2	6
Totals	30	27	15	20	28	23	23	24	26	166

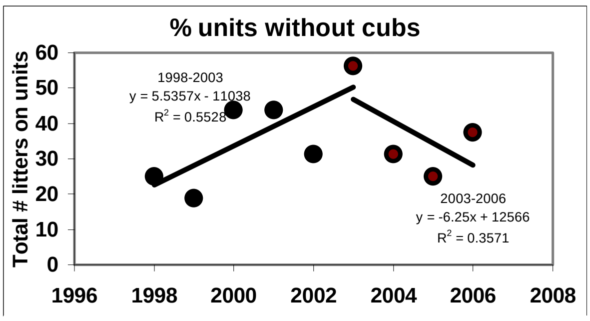

Figure 10. Percent of 16 monitoring sites without cubs in the Amur Tiger Monitoring Program, based on 9 years of monitoring, winter 1998 through 2006.

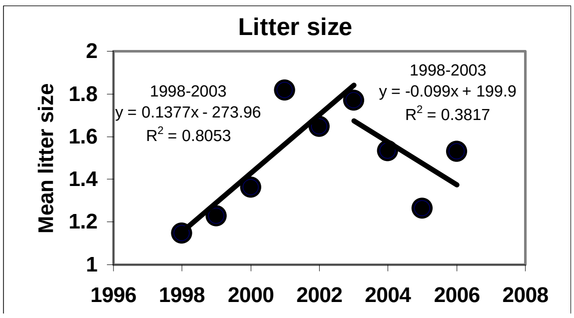

Figure 11. Mean litter size on 16 sites over 9 years of the Amur Tiger Monitoring Program, 1998 through 2006.

Estimation of productivity is difficult because sex ratios are often difficult to define in the adult population, but we can develop estimates of cub density to compare productivity across sites. For all years combined, there are dramatic differences between sites (Figure 12). Ussuriski Zapovednik appears to be far and away the most productive site. In general, cub density coincides with adult density, with cub density highest in the southern zapovedniks and lowest in the Khabaraovsk sites (Tigrini Dom, Botchinski Zapovednik, and Bolshekhekhetsirski Zapovednik).

Table 9. Litter size of all litters recorded in 9 winters of the Amur Tiger Monitoring Program, based on expert assessment of tracks.

	Litter size			
Year	1	2	3	Total #
1998	23	4	0	27
1999	17	5		22
2000	8	2	1	11
2001	4	5	2	11
2002	8	7	2	17
2003	7	2	4	13
2004	8	6	1	15
2005	14	5	0	19
2006	10	5	2	17
Total	75	31	10	152

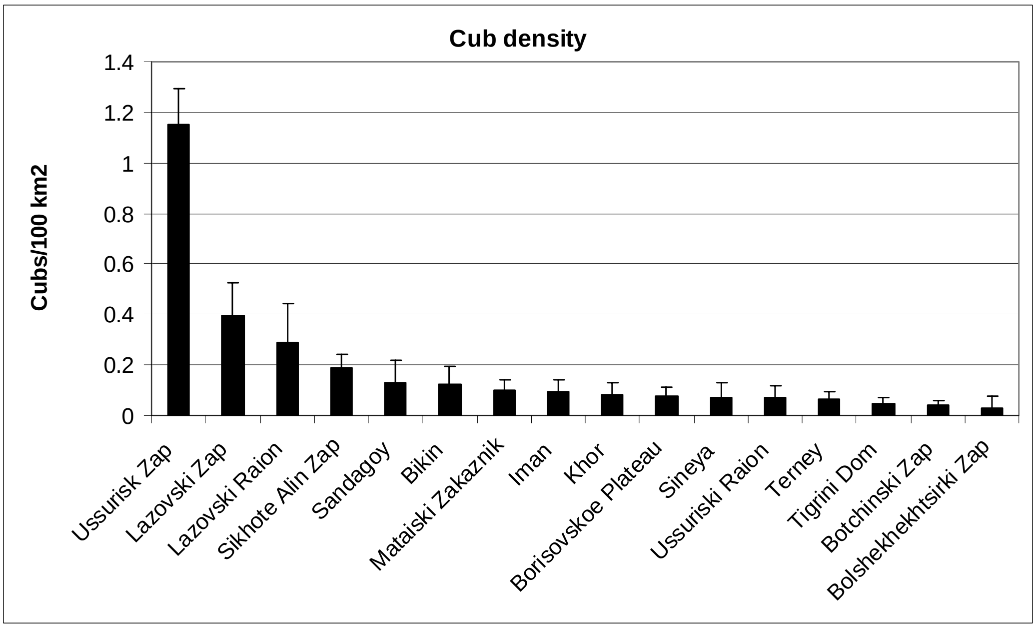

Figure 12. Cub density and 95% confidence interval, averaged across all nine years of the Amur Tiger Monitoring Program for each of the 16 sites.

Ungulate Populations on Monitoring Sites

Red deer, wild boar, and sika deer are the primary prey of Amur tigers. Roe deer are taken relatively infrequently, and may be considered secondary prey. On occasion, even musk deer and moose are taken. Of these 6 species, only wild boar and roe deer are relatively common across most of tiger habitat in the Russian Far East. Moose occur only in the northern half of tiger range, and red deer are rare in the southern third of tiger range. Sika deer occur mostly in the southern third where red deer are uncommon, and in fact there appears to be an inverse relationship in the relative abundance of red deer and sika deer. The boundaries of distribution of all species are shifting quite remarkably in the past 20 years, with the entire ecosystem "shifting" north: moose are being very uncommon in the central Sikhote-Alin; sika deer are expanding rapidly to the north, and red deer also appear to be retreating as sika deer replace them, especially along the eastern slopes of the Sikhote-Alin Range. These "natural" fluctuations which may be related to global climate change, make interpretation of the trends for ungulates more difficult. If we detect a downward trend for a given species, it is difficult to determine whether the change is a result of human impact, or climate-induced changes. Thus we should be aware of changes in ungulate numbers, but at the same time be careful in making assumptions about the causes of those changes.

We used track density as an indicator of ungulate abundance on Amur tiger monitoring units. As in previous years, prey numbers varied greatly among sites (Table 10). To attempt to understand how density estimates varied across monitoring sites and time, we conducted a regression analysis to look for trends across time, looking first at trends for all sites combined, and then separately for each site and each species. We conducted trend analyses for the entire nine years, or a subset of at least 7 years where a visual inspection suggested a significant trend might exist. We report all sites where the probability is less than 0.2 that the slope is not zero, with the understanding that we are looking for general trends and potential early warning signs across the region and within each monitoring site.

Table 10. Tracks/10 km of survey route on all 16 survey units of the Amur Tiger Monitoring Program for the 2005-2006 winter season. Mean density and standard deviation are provided for each survey unit.

	# transects sampled	Tracks/10 km on survey routes											
		Red deer		Wild boar		Sika deer		Roe deer		Musk deer		Moose	
	n	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Lazovski Zapovednik	12	4.67	6.90	2.57	4.56	120.40	174.28	1.29	2.71	0.00		0.00	
Lazovski Raion	11	0.09	0.28	1.00	2.29	36.31	53.19	0.41	0.82	0.00		0.00	
Ussuriski Zapovednik	11	3.04	3.17	9.21	9.51	18.63	24.40	2.42	3.82	0.07	0.24	0.00	
Iman	12	5.09	8.14	1.87	2.45	0.00	0.00	4.78	5.46	0.00		0.00	
Bikin	16	4.13	3.74	3.96	6.01	0.00	0.00	3.95	3.87	1.28	2.35	0.00	
Borisovskoe Plateau	14	0.00	0.00	11.16	17.80	20.72	15.05	2.26	2.15	0.34	1.28	0.00	
Sandagoy	16	4.08	5.10	1.74	2.12	1.35	1.60	4.39	6.34	0.29	0.72	0.00	
Khor	19	8.68	6.08	3.55	5.73	0.00	0.00	6.26	7.76	0.02	0.08	0.00	
Botchinski Zap	14	5.12	4.15	0.00	0.00	0.00	0.00	1.84	2.45	0.14	0.30	0.00	
Bolshekhekhtsirki Zap	7	42.75	35.13	4.60	7.75	0.00	0.00	3.22	3.85	0.00		0.00	
Tigrini Dom	14	2.01	1.89	0.24	0.91	0.00	0.00	2.17	2.17	0.31	0.42	0.00	
Mataiski Zakaznik	24	3.08	2.51	1.48	1.88	0.00	0.00	1.33	1.04	0.68	0.74	0.00	
Ussuriski Raion	12	0.86	1.10	2.68	1.82	2.45	3.41	4.22	7.51	0.00		0.00	
Sikhote Alin Zap	25	22.30	15.58	6.35	7.09	10.68	22.45	24.43	20.07	5.59	8.66	0.00	
Sineya	15	0.55	0.44	0.58	0.54	0.00	0.00	1.72	0.67	0.00		0.00	
Terney Hunting Lease	24	5.08	4.45	2.10	3.39	0.92	2.89	7.27	6.62	1.55	2.68	0.00	
Overall mean	246	6.58	11.99	3.26	6.60	10.89	47.63	5.53	10.10	0.94	3.35	0.00	

Red deer.

For the past three years, red deer track densities, averaged over all sites except Borisovkoe Plateau (where they are absent) have been remarkably steady, remaining lower than all previous 6 years of monitoring (Table 11, Figure 13). However, the overall pattern masks some interesting developments and trends in different portions of tiger range.

As in past years, red deer track densities varied greatly among monitoring sites, from 43 tracks/10 km in Bolshekhekhetsirski Zapovednik to 0 in Boriskovskoe Plateau, where they are no longer reported. And as in past years, track count densities of red deer were highest in Bolshe-Khekhtsirski Zapovednik, and secondly, in Sikhote-Alin Zapovednik (Table 10). These two reserves represent the only monitoring sites where track densities of red deer are high (> 22 tracks/10 km) with the Khor site coming in a distance third (8 tracks/10 km).

Across many of the monitoring sites in Primorye, red deer are decreasing in numbers, perhaps most noticeably in the south (Table 11, Figure 13). Sites in southern Primorye mostly have near zero densities (Borisovkoe Plateau, Lazovski Raion, Ussuriski Raion, and Sineya), and many people in the region attribute this decline to the fact that they are being outcompeted by an increasing sika deer population (whose increase may be a result of global climate change). However, this decline cannot be attributed solely to competition with sika deer or global climate change as nearby protected areas (Lazovski and Ussuriski Zapovedniks still retain reasonable track densities (3-4 tracks/10 km). In southeastern Primorye, sika deer are illegal to hunt, even though they are more abundant than red deer (there are presently strong pressures to remove this sika deer population from the federal endangered species list), which puts even greater hunting pressure on a red deer population that appears to be disappearing. Hence, probably for a combination of reasons (competition with sika deer, possibly climate change, and intense hunting pressure), red deer appear to be declining from southern Primorye except where they receive the highest level of protection (zapovedniks). In Southern Primorye, 3 monitoring sites are revealing significant or nearly significant downward trends in red deer numbers (Lazovski Raion, Ussuriski Zapovednik, and Sandagoy) (Figure 13a-c).

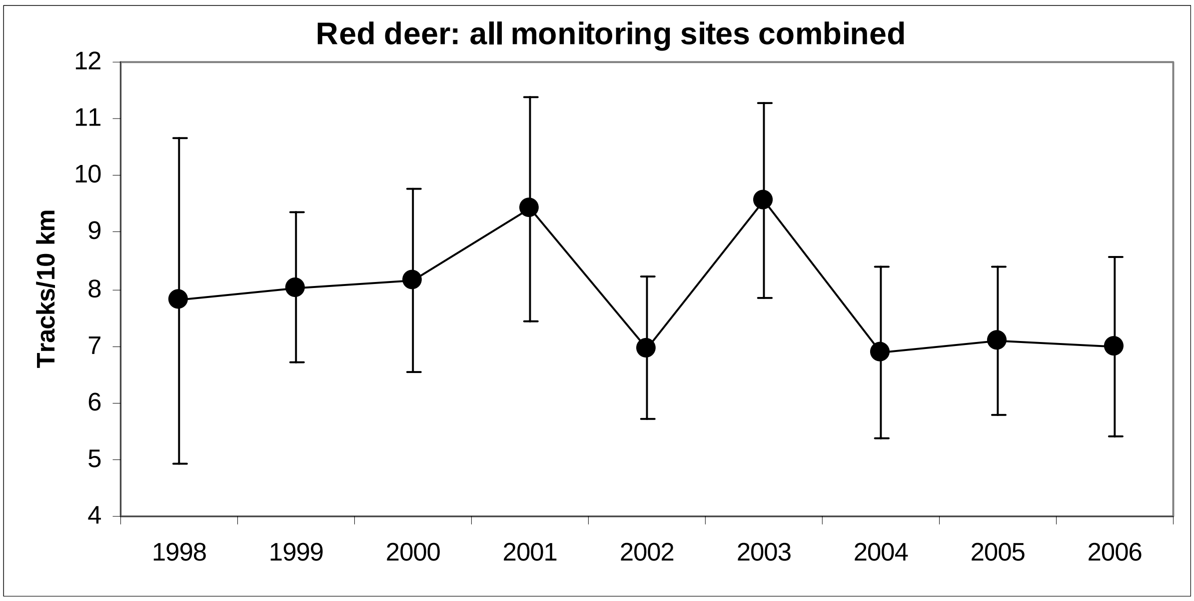

Figure 13. Average red deer track density and 95% confidence intervals for all sites except Borisovkoe Plateau (where red deer are absent) for nine years of the Amur Tiger Monitoring Program, 1998 though 2006.

Red deer numbers are also decreasing in central and northern Primorye. In Sineya, Bikin, Sikhote-Alin Zapovednik, and Terney Hunting lease, there are significant downward trends in red deer track densities (Figures 13d-g). While sika deer are increasing in Sikhote-Alin and Terney Hunting lease, they are rare or absent in Sineya and the Bikin. Thus, this factor alone is not sufficient to explain decreases in red deer numbers.

The only places where there is evidence that red deer may be increasing is in the two northern zapovedniks Bolshekhekhtsirski Zapovednik and the Khor monitoring site (Figure 13h-i). The trend is very strong in Bolshekhekhtsirski, but marginal in the Khor, and only over the past 7 years. In other sites across Khabarovsk, red deer numbers are fluctuating, but generally appear relatively stable (Matai, Botchinski Zapovednik, and Tigrini Dom).

Hence, overall, the population of red deer across many of the sites in Primorye appears to be in decline. The reasons for the decline are not completely clear, but may be related to several factors, including increases in Sika deer (see next section), climate change that is making conditions less favorable for red deer, and intense legal and illegal hunting. This last factor is the only one that can be reasonably addressed with management actions.

Table 11. Red deer track densities (tracks/10 km) counted along survey routes within all 16 monitoring units of the Amur Tiger Monitoring Program, 1998-2006.

	Tracks/10 km along survey routes									
	1998	1999	2000	2001	2002	2003	2004	2005	2006	Grand Total
Lazovski Zapovednik	1.23	1.49	6.94	9.16	3.92	1.14	5.53	4.30	4.67	4.27
Lazovski Raion	1.41	0.25	1.18	0.18	0.14	0.36	0.18	0.00	0.09	0.42
Ussuriski Zapovednik	6.06	7.03	6.98	5.03	3.33	4.66	3.56	5.00	3.04	4.97
Iman	1.79	6.33	5.34	5.56	8.10	6.35	5.36	7.05	5.09	5.66
Bikin	1.37	10.78	8.01	9.53	5.32	10.29	4.54	6.91	4.13	6.76
Borisovskoe Plateau	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sandagoy	1.87	3.84	9.90	7.41	9.87	6.87	5.07	4.67	4.08	5.95
Khor	5.69	6.82	3.98	4.29	4.83	13.28	6.35	8.99	8.68	6.99
Botchinski Zapovednik	1.75	6.87	4.33	2.92	4.69	5.26	11.58	4.49	5.12	5.22
Bolshekhekhtsirki Zapovednik	7.80	16.29	13.65	40.97	27.51	36.57	34.34	24.01	42.75	27.10
Tigrini Dom	3.00	5.06	1.38	1.60	2.47	2.39	1.69	0.76	2.01	2.26
Mataiski Zakaznik	1.71	4.85	3.76	2.21	4.96	9.63	3.61	5.41	3.08	4.36
Ussuriski Raion	2.16	2.02	4.28	1.79	1.38	2.72	1.48	2.70	0.86	2.15
Sikhote Alin Zapovednik	38.86	23.98	27.02	31.28	20.01	25.65	20.23	22.23	22.30	25.73
Sineya	1.68	4.00	2.77	3.35	1.50	2.25	1.82	1.64	0.55	2.17
Terney Hunting Lease	14.40	10.13	10.75	14.13	6.04	10.32	3.75	4.72	5.08	8.81
Grand Total	7.35	7.57	7.69	8.87	6.56	9.03	6.50	6.69	6.58	7.43

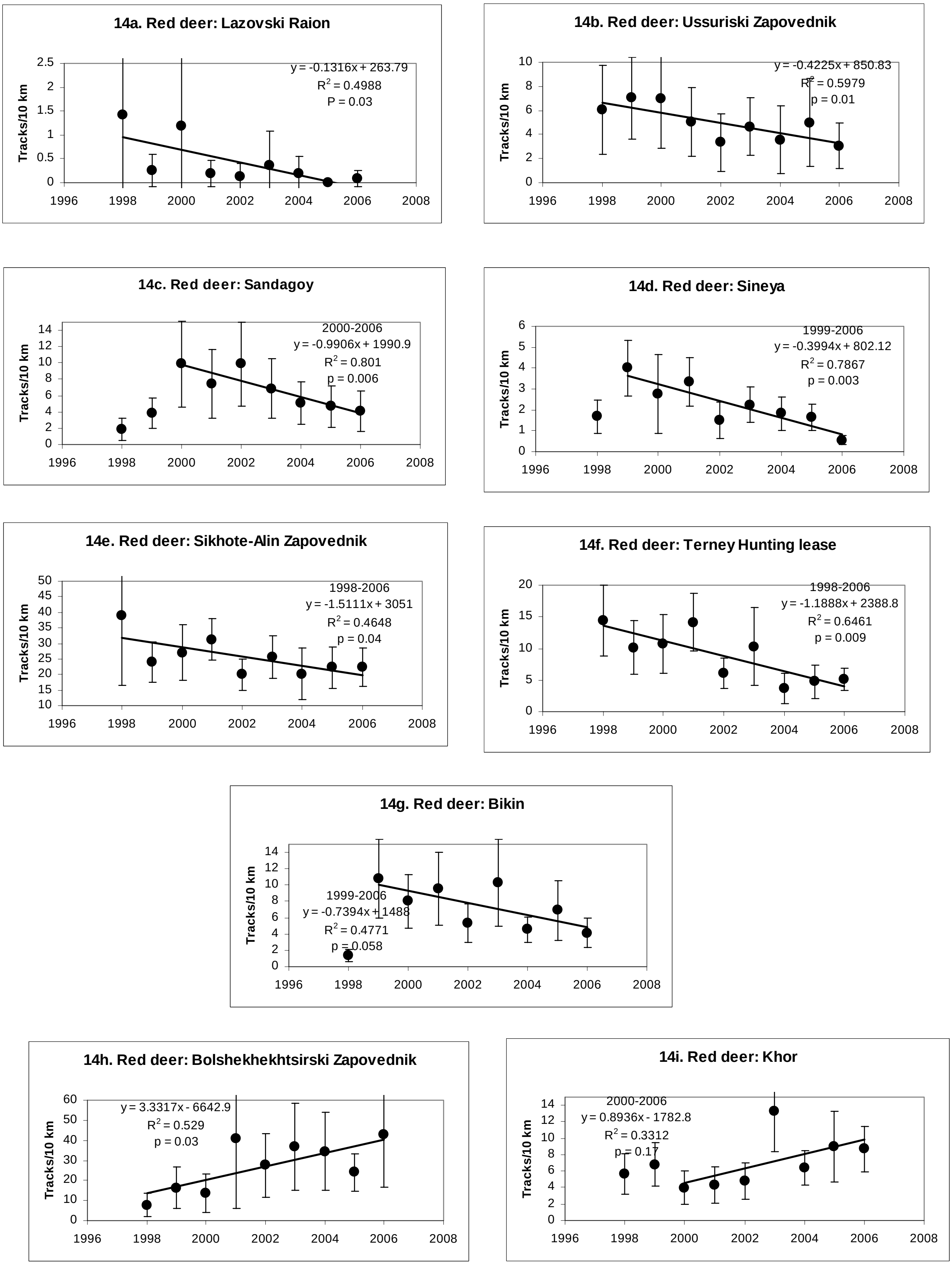

Figure 14a-i. Significant changes ($p < 0.2$) in red deer densities, as measured by fresh tracks/10 km along routes in 9 of the 16 monitoring sites of the Amur Tiger Monitoring Program. Trends were selected for a minimum of 7 years.

Wild boar.

Wild boar populations are known to fluctuate more dramatically than deer populations, and because they are commonly found in groups, are more problematic to accurately estimate density.

Wild boar track densities are generally lower than those of red deer (wild boar track density at all sites over 9 years = 3.6 ± 0.6 tracks/10 km, versus 7.5 ± 0.5 tracks/10 km for red deer) but fluctuate more from site to site than those of red deer, apparently because they have the capacity to move large distances in search of winter forage. In 2006 winter, wild boar densities averaged 3.25 + 0.8 tracks/10 km, very close to the 9-year average (Table 10). However, there appears to have been some substantial changes in wild boar numbers over the 9 years of the monitoring program (Table 12). The trend in average density across all sites suggests that wild boar numbers decreased during the first 4-5 years of monitoring, and then increased, with a low occurring in about 2002, with a subsequent rebound occurring through 2005, with perhaps a slight dip in 2006 (Figure 15). Unlike the situation for red deer, in which the average across all sites fails to reflect the local dynamics of the red deer populations (which are decreasing in some areas, increasing in others), the average for wild boar seems to fairly well depict what is happening across much of tiger range (Table 12, Figure 16). For instance, in Sikhote Alin Zapovednik as well as nearby Terney Hunting lease, wild boar track densities were relatively high at the beginning of the monitoring period, decreased to a low in 2002 when many wild boar carcasses were found along the coast, and then increased slowly over the past 6 years (Table 12, Figures 16a-b). Most of the other monitoring site showed similar, if not as clear, patterns, with a low around 2002 (e.g. Tigrini Dom, Figure 16c, and Bikin, Figure 16d). Only four of 16 sites demonstrated significant departures from this pattern. Wild boar in Lazovski Zapovednik increased from 1998 to 2004, and then decreased (Figure 16e); wild boar showed a relatively strong positive trend over the entire nine years (Figure 16f), as did boar in Borisovkoe Plateau (Figure 16g), while only in Sineya in Chuguevski raion did wild boar show a negative trend over all 9 years (Figure 16h).

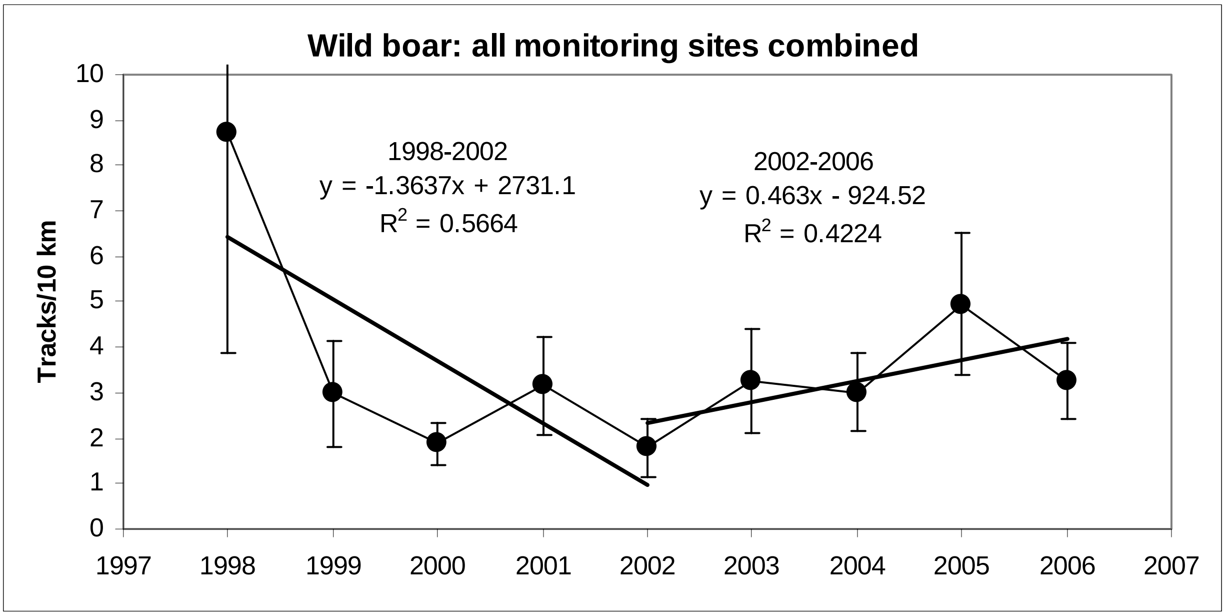

Figure 15. Average wild boar track density and 95% confidence intervals for all sites, for each of the nine years of the Amur Tiger Monitoring Program, 1998 though 2006.

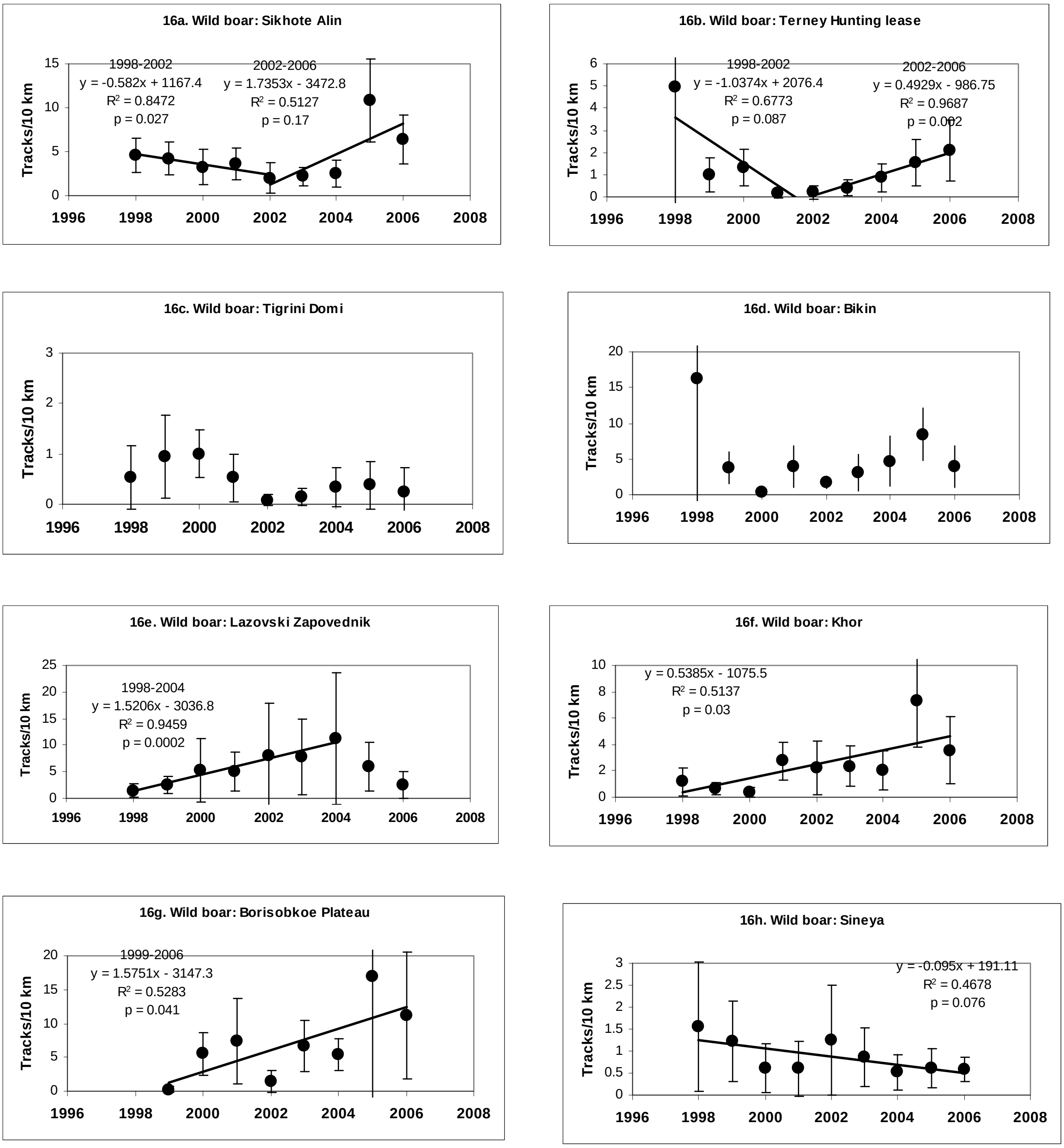

Figure 16a-h. Changes in wild boar densities, as measured by fresh tracks/10 km along routes in 8 of the 16 monitoring sites of the Amur Tiger Monitoring Program: wild boar decreased in abundance through 2002, and then increased through 2006, sometimes with clear significant regression equations (a-b), sometimes with weaker but similar trends (c-d). In 4 sites, wild boar showed positive growth trends across all years (Figure 16f) of some portion of those years (Figures 16e, 16g). Only in Sineya did wild boar numbers show a consistent negative trend (Figure 16h).

Table 12. Wild boar track densities (tracks/10 km) counted along survey routes within all 16 monitoring units of the Amur Tiger Monitoring Program, 1998-2006.

	Tracks/10 km along survey routes									
	1998	1999	2000	2001	2002	2003	2004	2005	2006	Grand Total
Lazovski Zapovednik	1.45	2.52	5.24	5.08	8.04	7.82	11.18	5.94	2.57	5.54
Lazovski Raion	3.28	0.30	0.30	0.27	1.63	1.99	3.48	0.75	1.00	1.45
Ussuriski Zapovednik	14.09	29.56	4.13	25.21	5.25	0.99	4.15	7.70	9.21	11.14
Iman	3.63	1.55	0.19	0.66	2.51	1.21	6.15	4.22	1.87	2.44
Bikin	16.32	3.80	0.30	3.97	1.69	3.08	4.67	8.46	3.96	5.14
Borisovskoe Plateau	91.09	0.26	5.53	7.47	1.38	6.64	5.42	16.91	11.16	16.21
Sandagoy	0.42	2.76	2.68	0.54	1.04	2.42	5.40	1.83	1.74	2.09
Khor	1.18	0.66	0.37	2.73	2.21	2.33	2.07	7.27	3.55	2.49
Botchinski Zapovednik	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bolshekhekhtsirki Zapovednik	0.80	3.16	0.61	3.52	2.46	28.82	4.89	2.12	4.60	5.67
Tigrini Dom	0.54	0.93	1.00	0.53	0.08	0.14	0.35	0.38	0.24	0.47
Mataiski Zakaznik	0.59	1.11	2.05	1.94	0.45	5.77	1.01	4.23	1.48	2.07
Ussuriski Raion	3.24	2.19	2.07	1.71	2.66	1.19	1.59	2.21	2.68	2.17
Sikhote Alin Zapovednik	4.60	4.21	3.25	3.57	2.01	2.16	2.48	10.81	6.35	4.38
Sineya	1.56	1.23	0.61	0.60	1.25	0.86	0.52	0.61	0.58	0.87
Terney Hunting Lease	4.98	0.97	1.33	0.15	0.20	0.40	0.86	1.53	2.10	1.39
Grand Total	8.71	2.98	1.87	3.17	1.80	3.25	3.01	4.95	3.26	3.67

In summary, across most sites, wild boar underway a decline through 2002 and then have started to rebound. Increases are not large, in most places, by the majority of sites provide indications of a slow increase over the past 4-6 years, with only a few exceptions. As a preferred food for tigers, this is good news, but densities are still very low, suggesting that more can be done to increase boar numbers across southern Russian Far East.

Sika deer.

Sika deer reach their highest densities in southern Primorski Krai, but also occur regularly in some of the central Amur tiger monitoring sites. Although there are reports of a few sika deer in Khabarovsk, they are mostly absent from this region (Table 10). Sika deer are found regularly in only eight of the monitoring units, including all 6 in the south, and 2 of the central monitoring sites (Table 10). However, in the two central units where they occur (Sikhote-Alin Zapovednik and Terney Hunting Lease) they exist in localized pockets, and are not uniformly distributed throughout the monitoring units. Sika deer appear to be increasing in the coastal areas of Terney Raion, and appear to be extending their range to the north, as more reports of sika deer are coming in from Khabarovsk and northern Terney Raion.

Track densities (and hence presumably animal densities) are generally much higher for sika deer than other ungulate species, reaching a peak of 183 tracks/10 km in Lazovski Zapovednik in 2005 (Table 10). Track densities average above 20/10 km on half of the 8 sites (Table 10). Highest track densities averaged across all years also occurs in Lazovski Zapovednik (Table 10).

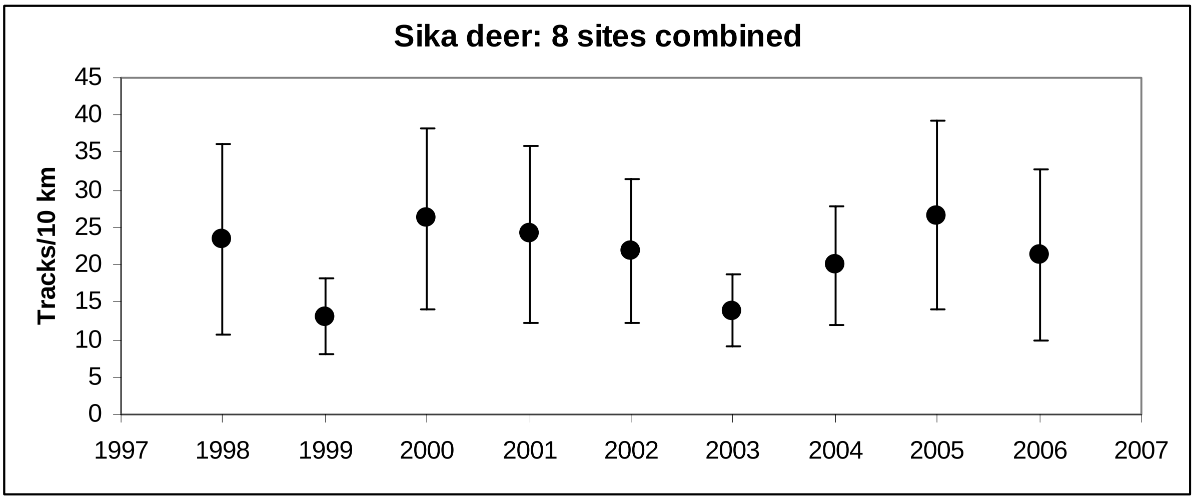

Figure 17. Average sika deer track density and 95% confidence intervals averaged across eight sites where they regularly occur, for nine seven years of the Amur Tiger Monitoring Program, 1998 though 2006.

Sika deer are highly gregarious, and there is great variation in track counts dependent on the number of groups encountered along transects. Greater sampled is probably required to obtain more accurate estimates of track densities, with smaller confidence intervals. No significant trends appear across the 8 southern sites for the 7 years of monitoring, but there are trends for some of the individual sites (Figure 23).

Despite this apparent trend of range extension, the data across all 8 sites where sika deer normally occur does not suggest that, overall, sika deer numbers are increasing at those sites (Figure 17), but rather, suggests a relatively stable situation exists in general across the region.

Table 13. Sika deer track densities (tracks/10 km) counted along survey routes within all 16 monitoring units of the Amur Tiger Monitoring Program, 1998-2006.

	Tracks/10 km along survey routes									
	1998	1999	2000	2001	2002	2003	2004	2005	2006	Grand Total
Lazovski Zapovednik	45.18	43.85	108.28	123.38	92.46	42.71	83.71	183.46	120.40	93.71
Lazovski Raion	9.31	11.43	41.79	51.64	47.30	28.96	30.34	37.40	36.31	32.72
Ussuriski Zapovednik	22.56	16.12	30.72	26.65	23.09	11.18	22.95	17.76	18.63	21.07
Iman	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bikin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Borisovskoe Plateau	116.29	42.87	65.74	20.81	32.51	18.58	28.29	19.89	20.72	40.63
Sandagoy	0.91	2.46	4.06	7.91	4.27	2.86	1.26	1.27	1.35	2.93
Khor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Botchinski Zapovednik	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bolshekhekhtsirki Zapovednik	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tigrini Dom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mataiski Zakaznik	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.01
Ussuriski Raion	0.59	0.34	2.69	1.98	1.23	0.96	0.62	1.30	2.45	1.35
Sikhote Alin Zapovednik	10.24	5.18	4.68	8.71	11.52	15.85	18.04	7.80	10.68	10.30
Sineya	0.19	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Terney Hunting Lease	5.20	1.61	1.73	0.47	0.75	2.68	1.17	0.38	0.92	1.66
Grand Total	11.89	6.68	13.30	12.25	11.09	7.05	10.14	13.52	10.89	10.76

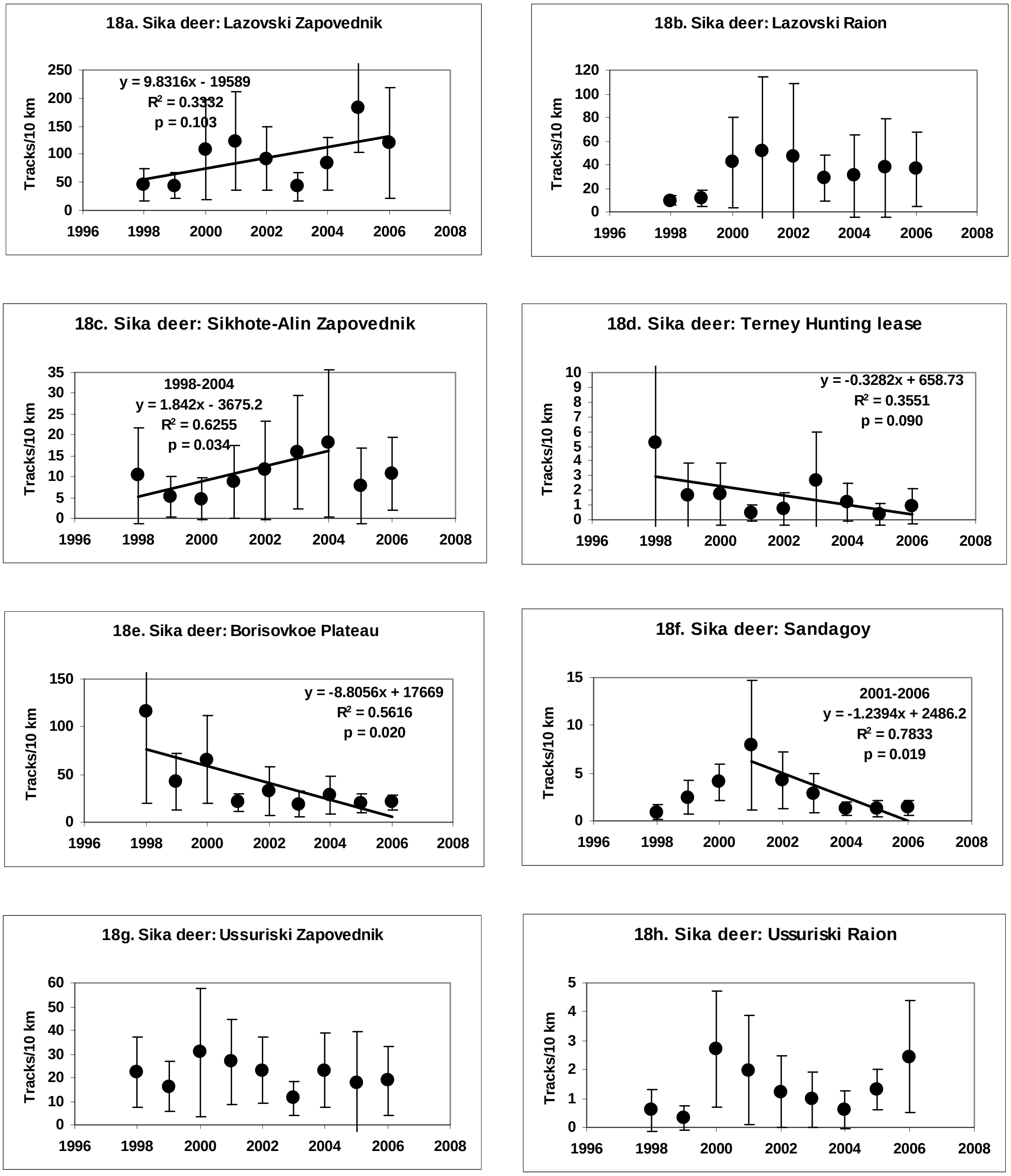

Figure 18a-h. Changes in sika deer densities, as measured by tracks/10 km along routes in all 8 monitoring sites where this species occurs in the Amur Tiger Monitoring Program, 1997-1998 through 2005-2006.

Because sika deer are highly gregarious, great variation in track counts occurs dependent on the number of groups encountered. Hence, tight confidence intervals are difficult to obtain when sampling sika deer (the same problem exists with wild boar, another grouping animal). Nonetheless, there are individual sites where sika deer numbers appear to be increasing and decreasing. Track indices suggest that sika deer numbers are increasing in Lazovski Zapovednik across the 9-year sampling period (Figure 18b), although in nearby Lazovski raion, sika deer track indices suggest numbers have been stable since 2000 (Figure .18b). In Sikhote-Alin Zapovednik, sika deer numbers appeared to be increasing through 2004, and then have perhaps stabilized over the past two years, whereas in neighboring Terney Hunting lease, there is a noticeable (though not highly significant) downward trend, which matches the downward trend there in red deer (Figure 13f). In Borisovkoe Plateau, where many believe sika deer densities are high, our analysis indicates that sika deer numbers appear to be dropping from a high at the beginning of the monitoring period (Figure 18e), and are now at a level much lower than that found in Lazovski Zapovednik. In Sandagoy (Figure 18f), sika deer numbers may have increased through 2001. and then decreased, while in Ussurisk Zapovednik and raion (Figure 18g-h), numbers appear to fluctuate (with large confidence intervals), with no clear trends.

The overall results suggest that in a few of the protected areas (Lazovski and Sikkhote-Alin Zapovednik) sika deer numbers may be decreasing, but outside protected areas, numbers are either falling (e.g. Borisovkoe Plateau and Terney Hunting lease) or fluctuating with no clear trends (e.g. Ussuriski and Lazovski raions).

Sika deer versus red deer. Right now the situation in Primorski Krai surrounding Sika deer is quite controversial. Sika deer populations in Southeast Primorski Krai are protected as an endangered subspecies, but hunting is allowed on them elsewhere, for instance, in Southwest Primorye, in places such as Borisovkoe Plateau. Many people have noted that there is an inverse relationship between the abundance of red deer and sika deer, i.e., as sika deer numbers increase, through some mechanism (competition, or perhaps disease) red deer numbers decrease. Most of the information available to corroborate this trend is largely anecdotal. We use the data collected from four sites (Lazovski raion, Ussuriski Zapovednik Sikhote-Alin Zapovednik and Terney Hunting lease) where red deer numbers have decreased significantly over the nine years of the monitoring period, and where sika deer also occur, to determine whether there is a negative relationship between sika deer abundance and red deer abundance.

We used a curve-fitting program (CurveExpert 1.3) to derive the best fit of linear and nonlinear models. The result produced a Rational Function where y=(a+bx)/(1+cx+dx^2) and where the coefficient data was calculated as:

a =	-0.26032243
b =	1.9926929
c =	-0.19926879
d =	0.021215785

The resulting graph of the relationship of red deer and sika deer densities is quite interesting (Figure 19) in that it suggests that red deer and sika deer populations can both increase when densities of both are relatively low. However, there appears to be a critical density of sika deer (after 25 tracks/10 km) where red deer densities begin to decline quite dramatically, and by the time sika deer densities approach 50 tracks/10 km, red deer are nearly absent from such sites.

While this analysis is preliminary, it does suggest that there is a clear relationship between the abundance of sika deer, and the decline of red deer in a given area. The reason for such a decline is still open to debate, but the relationship appears to be relatively clear, in that red deer can thrive in areas where sika deer densities are relatively low, but once they reach a critical density, red deer seem to be eliminated from the area. Sika deer have the capacity to reach densities that have rarely been reported for red deer, and hence, as a source of food for tigers, assuming tigers have equal success in capture, the total biomass provided by sika deer will be considerably greater than that of red deer, even though the body mass of red deer is considerably greater than of sika deer.

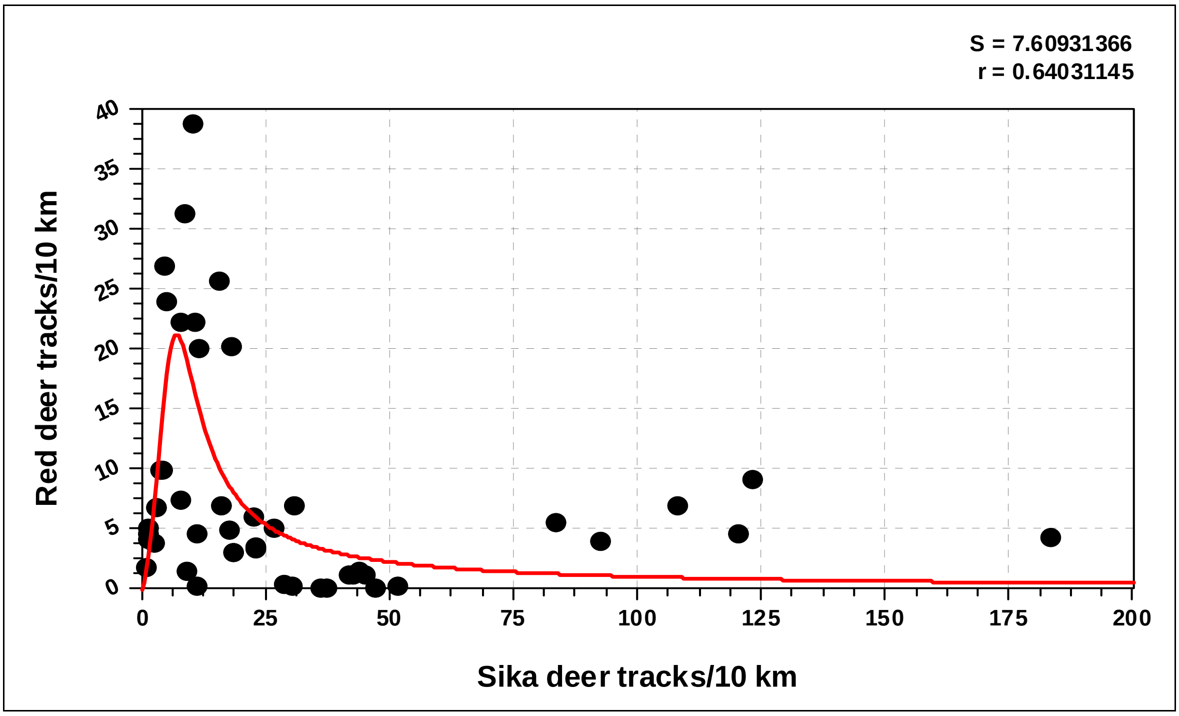

Figure 19. Track densities of red deer and sika deer, plotted for 4 sites where red deer numbers have decreased through the nine years of the Amur Tiger Monitoring Program, and where sika deer numbers are also present.

Roe deer.

Roe deer are the only ungulate species that is found on all 16 monitoring sites. In the 2005-2006 winter the average roe deer track index was 5.56 $\pm$ 1.26 tracks/10 km of survey route (Table 10). This estimate varies little from the 9-year average (5.41 $\pm$ 0.41) (Table 14). In fact the overall density averaged across all sites has varied very little across all nine years, from a low of 4.98 $\pm$ 1.09 to a high of 6.15 $\pm$ 1.36 in 2003 (Table 14).

As with red deer, there is evidence that roe deer densities are decreasing in many of the southern monitoring units (Figure 21a-d). In two pairs of adjacent monitoring sites in the south (Lazovski Zapovednik-Lazovski raion and Ussuriski Zapovednik-Ussurisk raion) thee is strong evidence of decreases in roe deer numbers across all sites. In Borisovkoe Plateau, there is also a less pronounced downward trend (not show here). However, in many of the central (Figures 21e-f) and northern sites ((Figures 21g-h), there is evidence that roe deer numbers are increasing. However, while the trend in the south appears fairly consistent, such is not the case in the central and northern sites, as demonstrated by Tigrini Dom (Figure 21j) and Mataiski Zakaznik (Figure 21k) where patterns are inconsistent, but with evidence at least in Matai, of a potentially slight decrease over the past 6 years. The results thus suggest that roe deer numbers may be undergoing significant declines in southern Primorye, while the situation in the central (northern Primorye) and northern (southern Khabarovsk) zones is more mixed, with increases in some areas, and no clear trends in others. It is worth noting that across the central and northern zones, there is no evidence that roe deer numbers are declining in any of the monitoring sites.

Table 14. Roe deer track densities (tracks/10 km) counted along survey routes within all 16 monitoring units of the Amur Tiger Monitoring Program, 1998-2006.

	Tracks/10 km along survey routes									
	1998	1999	2000	2001	2002	2003	2004	2005	2006	Grand Total
Lazovski Zapovednik	4.30	2.40	3.90	2.73	4.07	0.62	0.97	2.47	1.29	2.53
Lazovski Raion	3.42	1.01	0.67	0.11	1.30	0.10	0.97	0.35	0.41	0.93
Ussuriski Zapovednik	13.81	8.61	10.33	6.49	6.14	2.18	1.53	2.02	2.42	5.95
Iman	3.38	2.68	2.98	4.45	4.29	6.83	3.76	5.01	4.78	4.24
Bikin	1.49	4.83	1.74	2.88	4.49	3.41	4.70	5.43	3.95	3.66
Borisovskoe Plateau	3.38	8.48	4.58	6.22	8.42	2.69	4.36	3.78	2.26	4.91
Sandagoy	2.50	2.44	6.70	8.98	11.94	6.39	3.26	3.94	4.39	5.62
Khor	2.69	7.60	2.73	3.35	6.07	5.01	6.45	7.15	6.26	5.26
Botchinski Zapovednik	0.42	3.00	2.69	4.24	3.91	6.44	7.78	2.40	1.84	3.64
Bolshekhekhtsirki Zapovednik	0.45	1.27	0.16	0.92	4.53	0.68	4.63	1.46	3.22	1.92
Tigrini Dom	0.65	1.04	0.36	0.32	0.67	0.09	0.47	0.17	2.17	0.66
Mataiski Zakaznik	1.37	2.62	2.10	1.53	1.43	4.11	1.55	1.53	1.33	1.95
Ussuriski Raion	7.93	7.92	12.05	7.86	4.65	1.90	2.46	2.54	4.22	5.73
Sikhote Alin Zapovednik	17.60	11.50	20.05	16.77	14.32	21.75	21.43	16.27	24.43	18.23
Sineya	2.48	2.59	2.37	3.96	2.92	5.40	2.15	4.39	1.72	3.11
Terney Hunting Lease	7.32	5.38	5.52	8.24	4.15	11.08	6.33	6.90	7.27	6.91
Grand Total	5.05	4.98	5.54	5.60	5.55	6.15	5.40	4.90	5.53	5.41

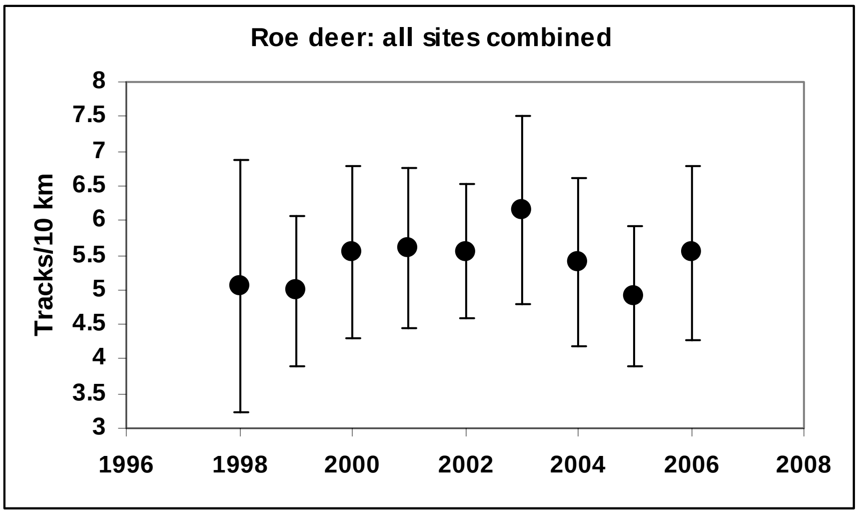

Figure 20. Average roe deer track density averaged across for all study sites, for nine years of the Amur Tiger Monitoring Program, 1997-1998 though 2005-2006.

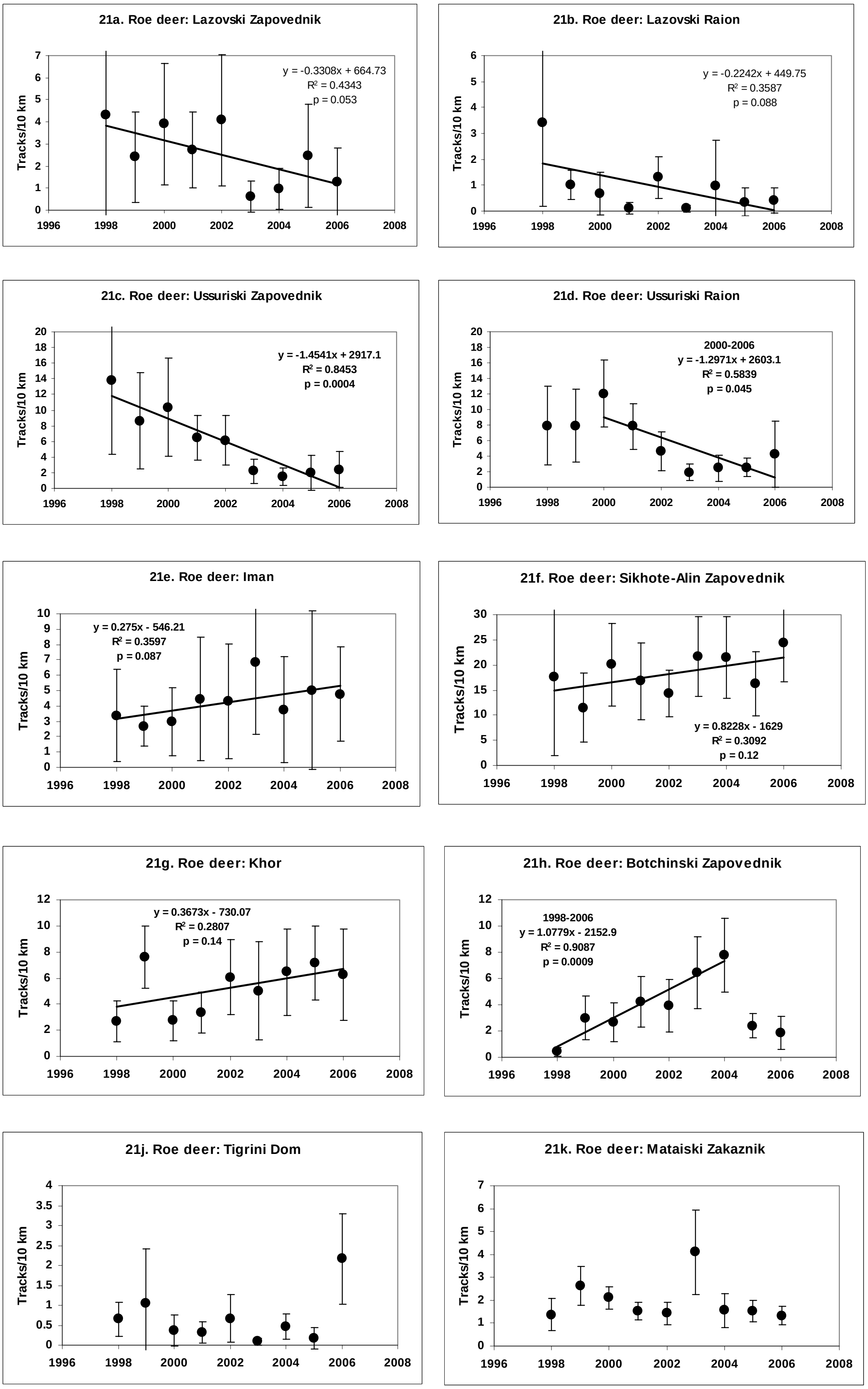

Figure 21a-k. Changes in roe deer densities, as measured by tracks/10 km along routes in ten monitoring sites in the Amur Tiger Monitoring Program, 1997-1998 through 2005-2006.

Roe deer versus sika deer. Whether decreases in roe deer numbers in the south are also related to increases in sika deer numbers, as appears to be the case with red deer, has not been investigated at all. We plotted track density of sika deer versus roe deer for the eight monitoring units where the two species co-occur, and used the same approach as with red deer to derive the best fit of linear and nonlinear models. The resulting model is very similar to that derived between red deer and sika deer (Figure 22). Employing a rational function of the form y=(a+bx)/(1+cx+dx^2), the coefficient variables derived are:

a = 3.6323795
b = 1.0405012
c = -0.09497496
d = 0.010798039

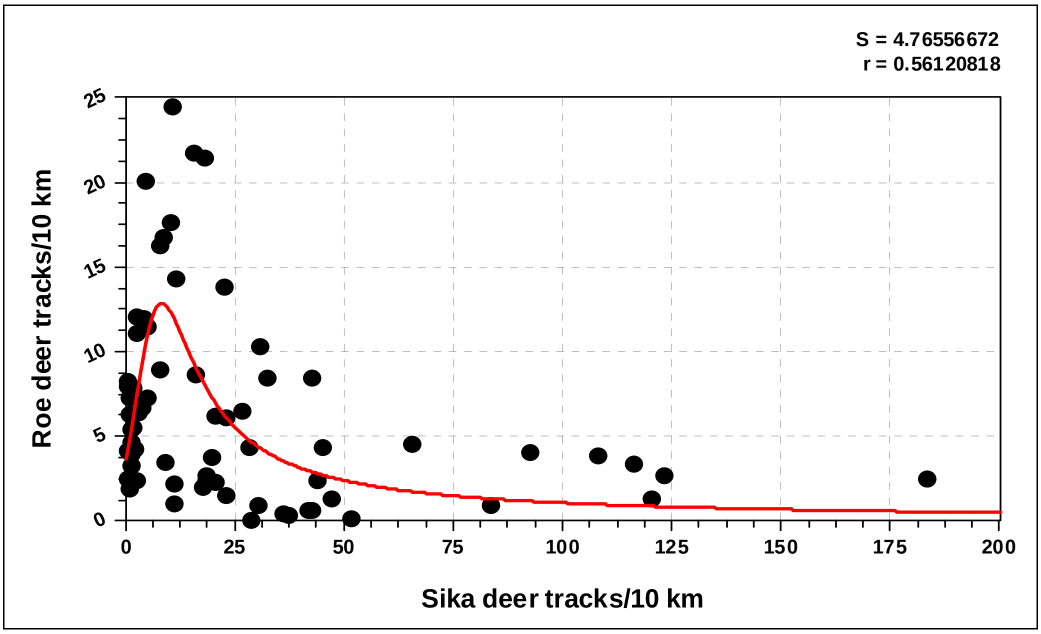

Figure 22. Track densities of roe deer and sika deer, plotted for 4 sites where roe deer numbers have decreased through the nine years of the Amur Tiger Monitoring Program, and where sika deer numbers are also present.

As with red deer, this model suggests that at low densities sika deer do not seem to have an impact on roe deer densities, and in fact, both can increase simultaneously. However, once sika deer densities reach some critical level (about 50 tracks/10 km, slightly greater than for red deer), then roe deer densities begin to drop quite dramatically, and while the do not seem to disappear from a system, levels remain below 5 tracks/ 10 km. The mechanisms responsible for these relationships are still speculative, but it appears that sika deer are capable of reaching extremely high densities, to such an extent that they are pushing other tiger prey species either completely out of systems, or in marginal existences. Clearly the relationships of these ungulates is an interesting and pertinent point in terms of how changes in population dynamics of specific prey species can impact the entire prey complex. How these changes affect tiger densities is still open to question. Assuming equal capture probability, higher prey biomass should be a good thing for tigers. This issue is certainly worthy of further examination.

Musk deer

Data collection on musk deer only began in 2001 for the Amur Tiger Monitoring Program. Musk deer are largely associated with spruce-fir forests, which are generally not considered prime habitat for tigers. Hence, musk deer are unlikely to be a common feature of monitoring units. Nonetheless, because the do on occasion become prey for tigers, it is worth assessing their abundance on monitoring units.

Over the six years that musk deer have been monitored, they have been reported on 15 of 16 units (Table 15), but they regularly occur on only 10 monitoring units (presence in at least 4 of 6 years). Of those, highest densities are reported for Sikhote-Alin Zapovednik (6-year average 4.72 ± 1.8) with Terney Hunting lease in second (2.36 ± 0.87) (Table 15).

Table 15. Musk deer track densities (tracks/10 km) counted along survey routes within all 16 monitoring units of the Amur Tiger Monitoring Program, 1998-2006.

	Tracks/10 km along survey routes									
	1998	1999	2000	2001	2002	2003	2004	2005	2006	Grand Total
Lazovski Zapovednik	0.51	0.00	0.00	0.78	0.00	0.09	0.00	0.00	0.00	0.15
Lazovski Raion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ussuriski Zapovednik	0.00	0.00	0.00	0.44	0.00	0.15	0.00	0.03	0.07	0.08
Iman	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.02
Bikin	0.50	0.25	0.00	5.20	2.62	2.11	0.67	1.94	1.28	1.62
Borisovskoe Plateau	0.00	0.00	0.00	0.63	0.40	0.07	0.19	0.09	0.34	0.19
Sandagoy	0.42	0.00	0.00	1.69	0.28	0.33	0.32	0.75	0.29	0.45
Khor	0.04	0.00	0.00	0.15	0.00	0.07	0.34	0.04	0.02	0.07
Botchinski Zapovednik	0.00	0.00	0.00	0.42	1.29	0.98	0.35	0.29	0.14	0.39
Bolshekhekhtsirki Zapovednik	0.00	0.00	0.00	0.50	1.27	0.00	0.00	0.00	0.00	0.20
Tigrini Dom	0.00	0.00	0.00	0.20	0.37	0.49	1.01	0.35	0.31	0.30
Mataiski Zakaznik	0.00	0.00	0.00	2.69	1.86	2.48	1.37	1.07	0.68	1.13
Ussuriski Raion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Sikhote Alin Zapovednik	0.00	0.00	0.00	15.51	3.13	4.73	6.29	7.27	5.59	4.72
Sineya	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.03	0.00	0.01
Terney Hunting Lease	0.00	0.04	0.00	8.69	1.32	4.04	2.12	3.48	1.55	2.36
Grand Total	0.09	0.02	0.00	3.30	0.97	1.39	1.16	1.41	0.94	1.03

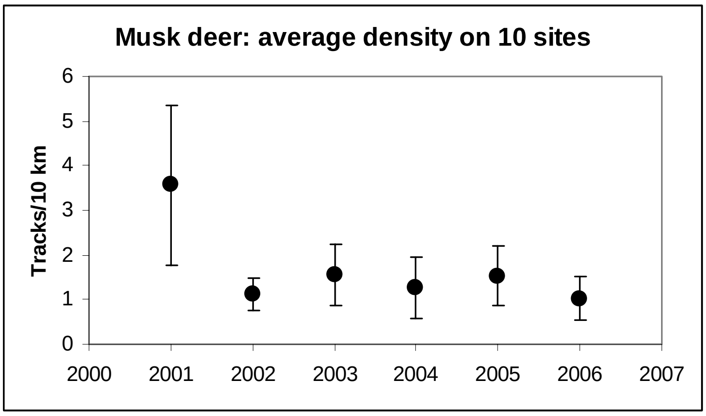

Figure 23. Musk deer track density averaged across 10 study sites where they regularly occur, for six years of the Amur Tiger Monitoring Program, 2001 though 2006.

A review of trends in specific monitoring units suggests a very different picture from the overall average trend (Figures 24). In four survey units there are significant downward trends in musk deer densities. Four of the 10 sites show strong negative trends (Figures 24a-d) while the negative trend seen in Terney Hunting lease may be the result of an outlying large first value in 2001 (Figure 24e). Sikhote-Alin Zapovednik, which has the highest estimate of musk deer density, appears to have a relatively stable population. However, outside protected areas, musk deer are being heavily hunted for the musk pod, and these declining population trends are likely a reflection of this intensive hunting.

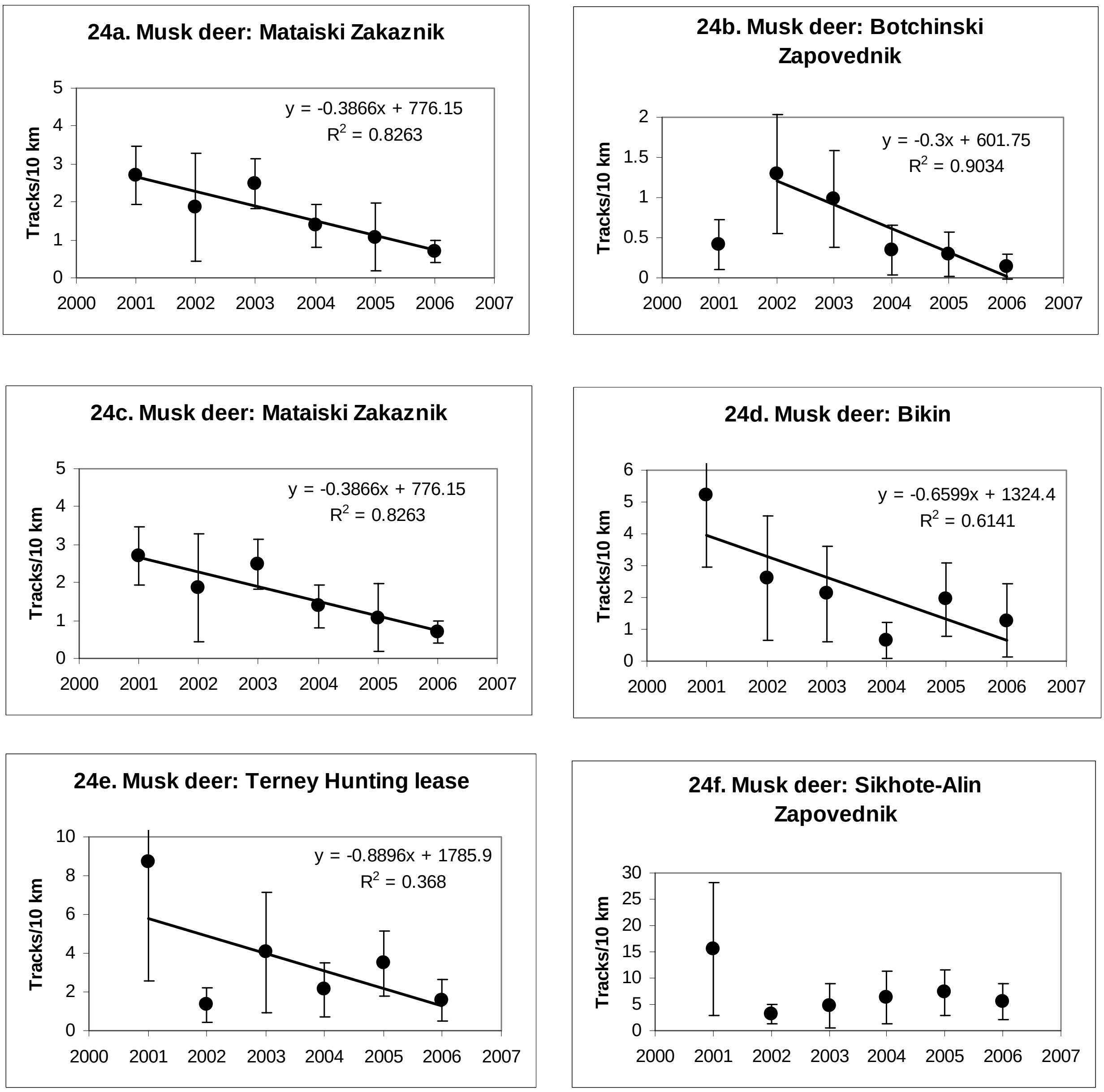

Figure 24. a-k. Changes in musk deer densities, as measured by tracks/10 km along routes in six monitoring sites in the Amur Tiger Monitoring Program, 1997-1998 through 2005-2006.